

GB 2412682 A continuation

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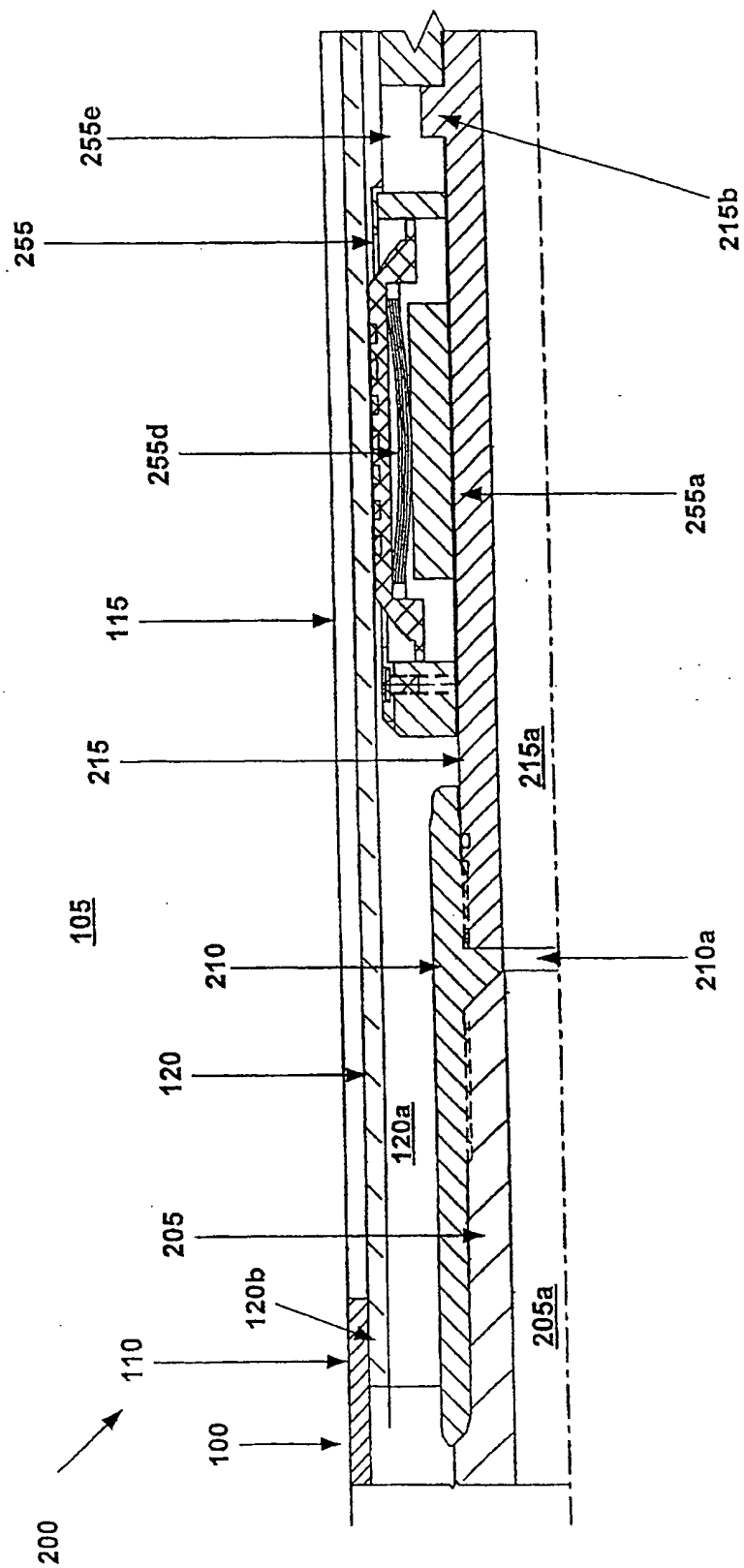


Fig. 1a

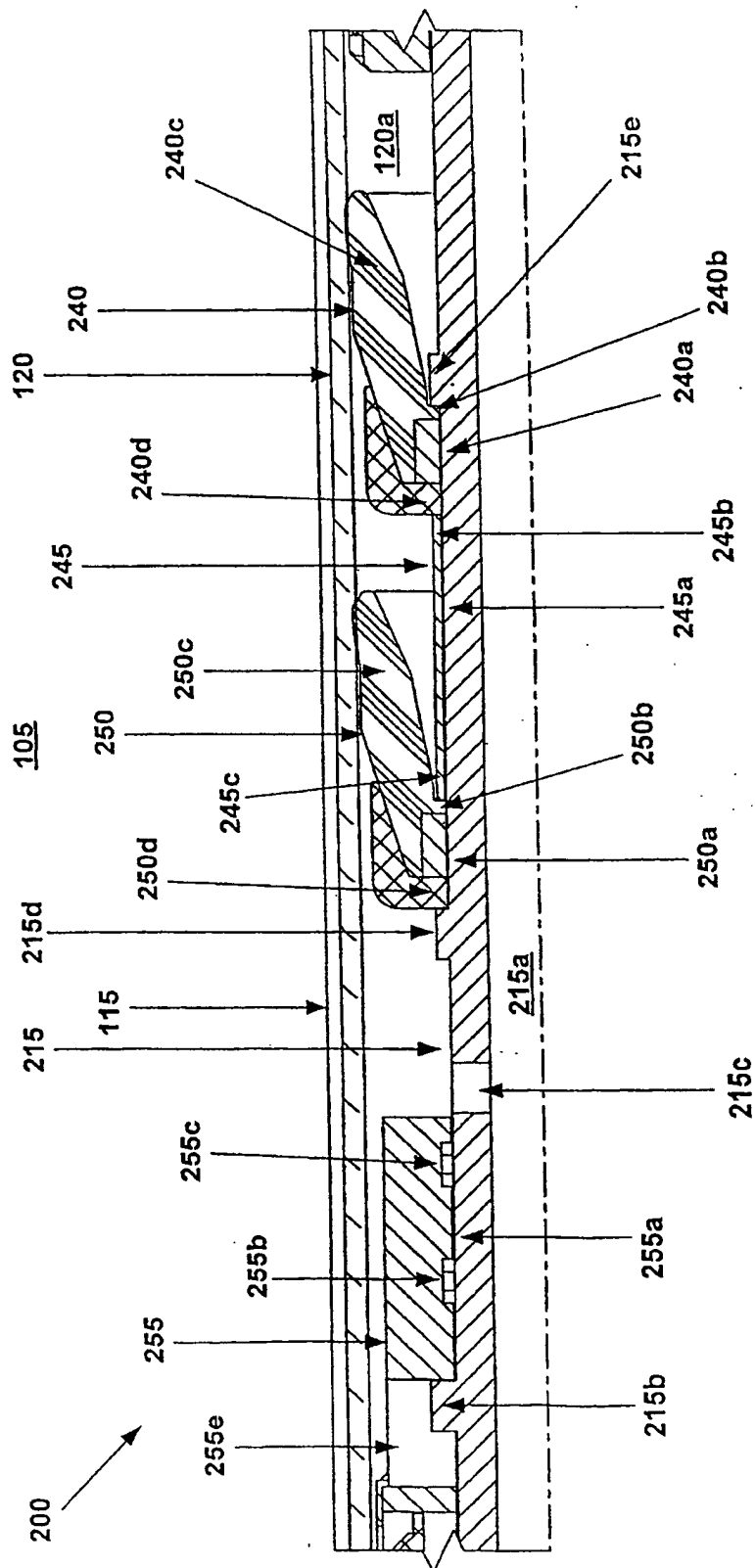


Fig. 1b

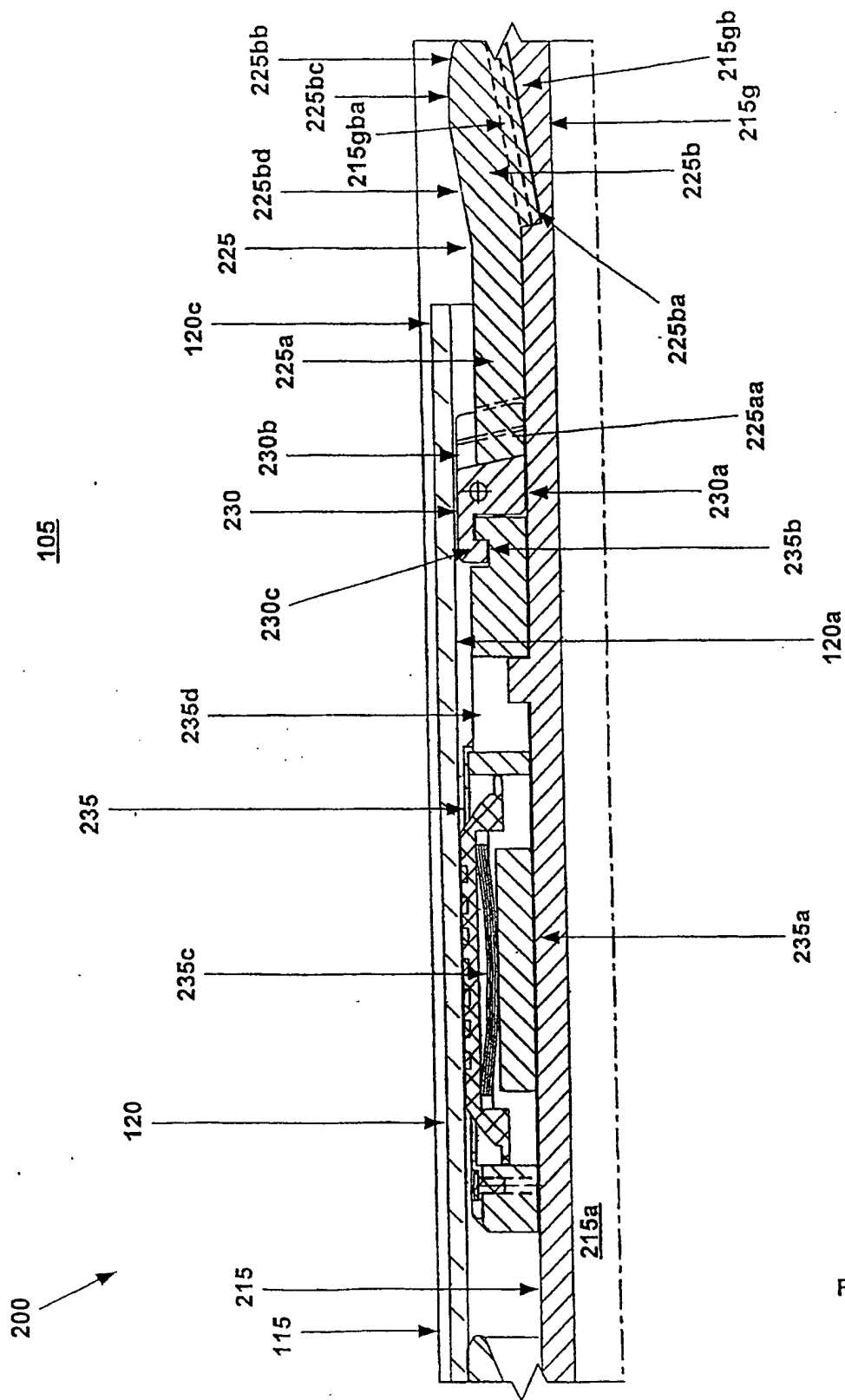


Fig. 1c

105

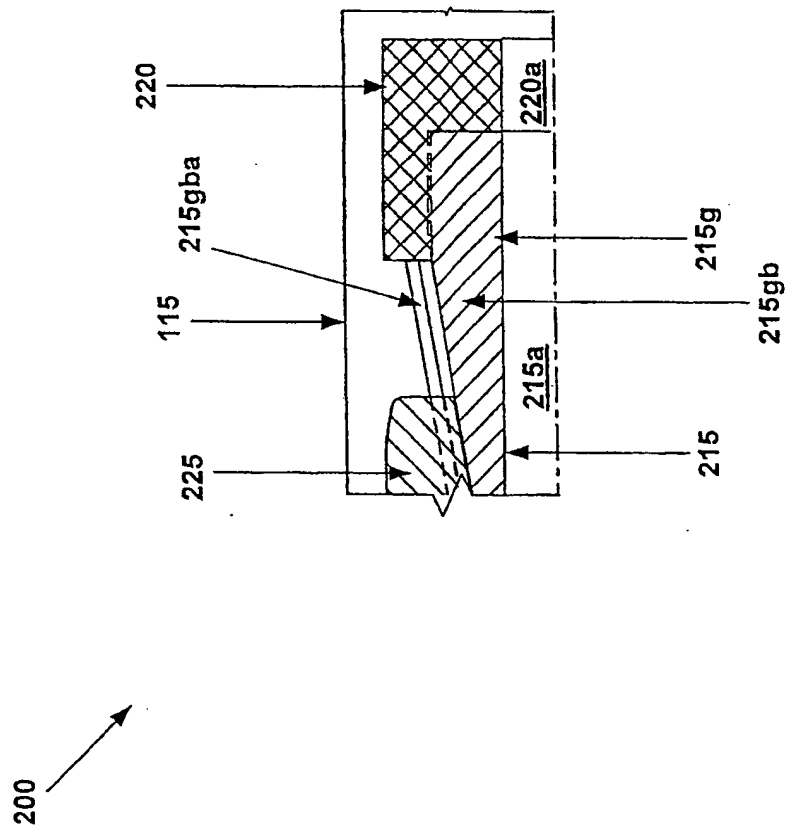
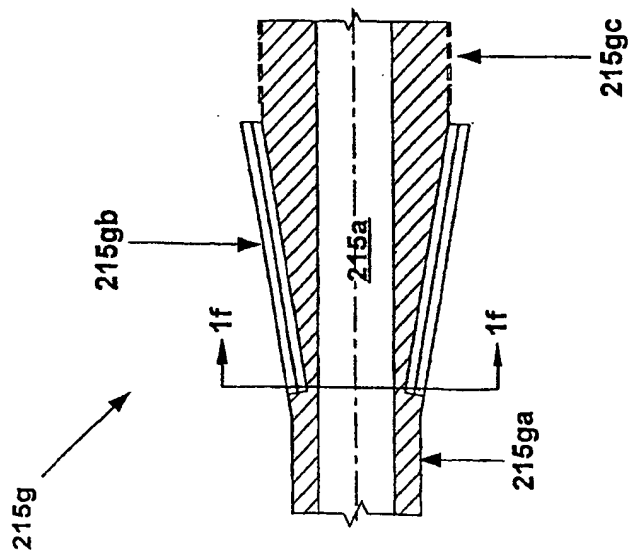
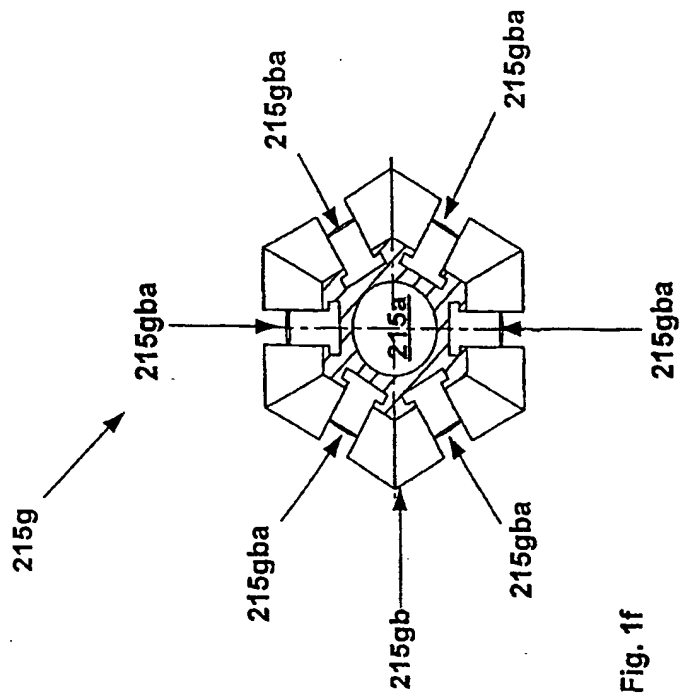


Fig. 1d



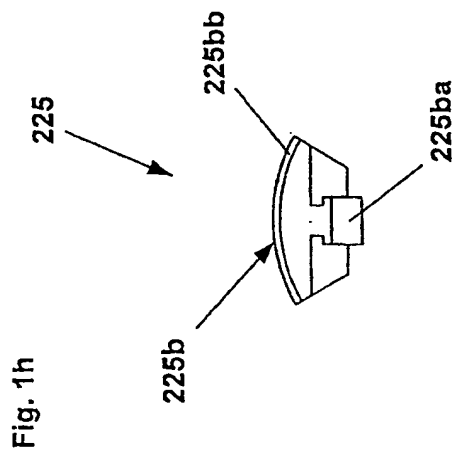


Fig. 1h

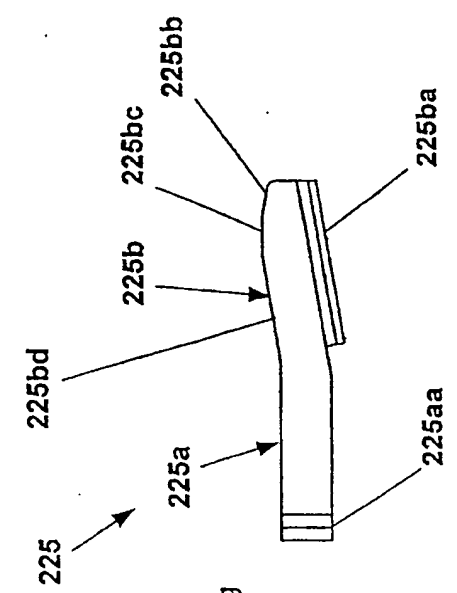
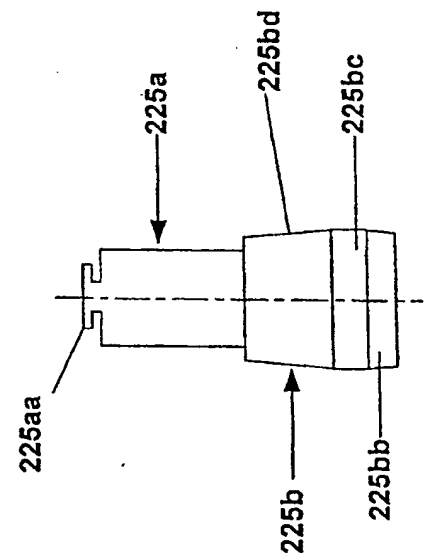


Fig. 1g



Fig. 1i



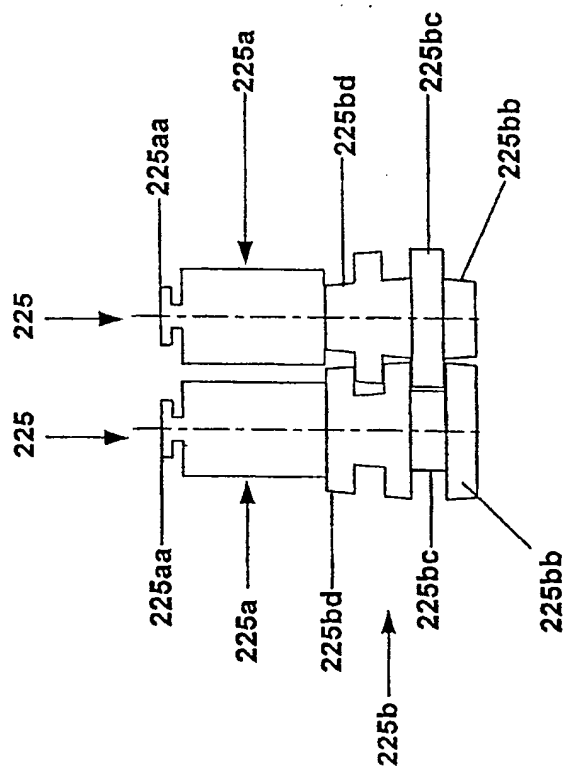


Fig. 1j

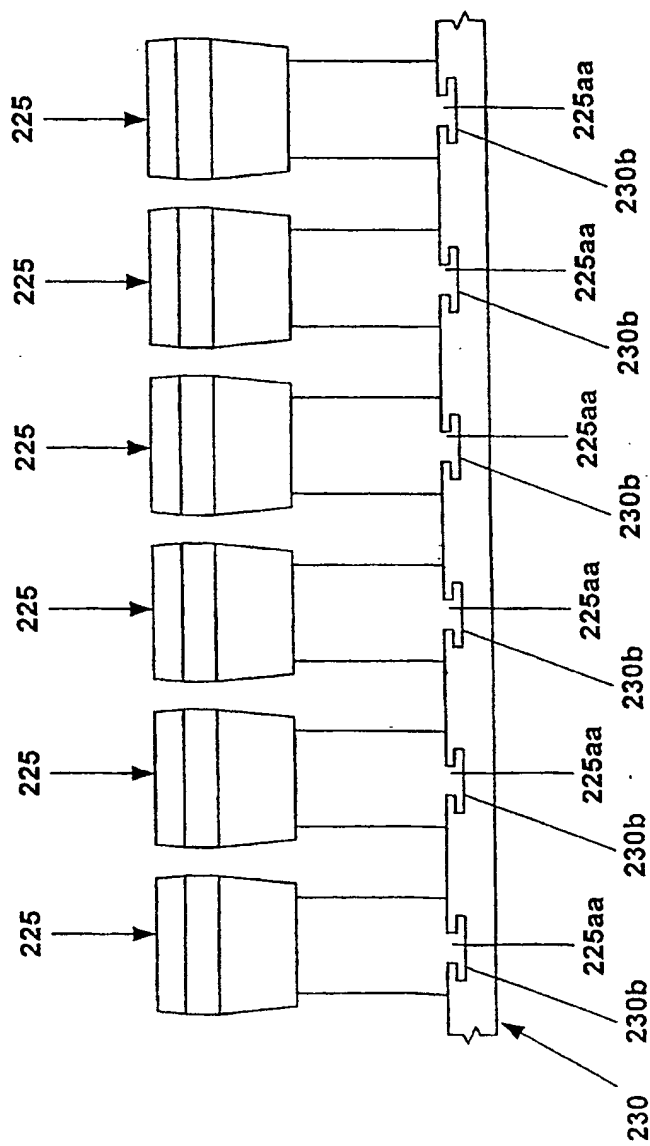


Fig. 1k

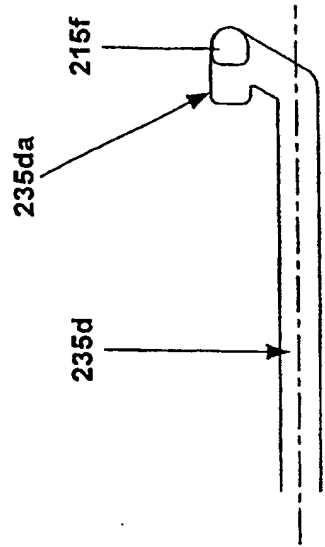


Fig. 1m

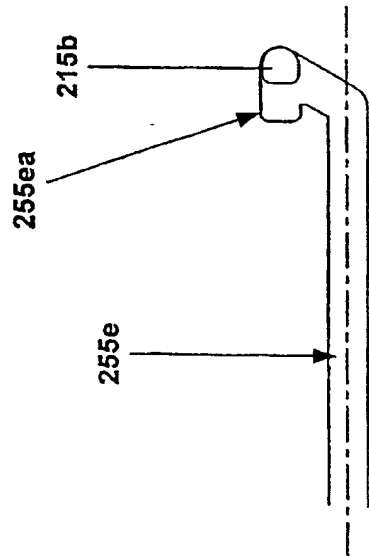


Fig. 1l

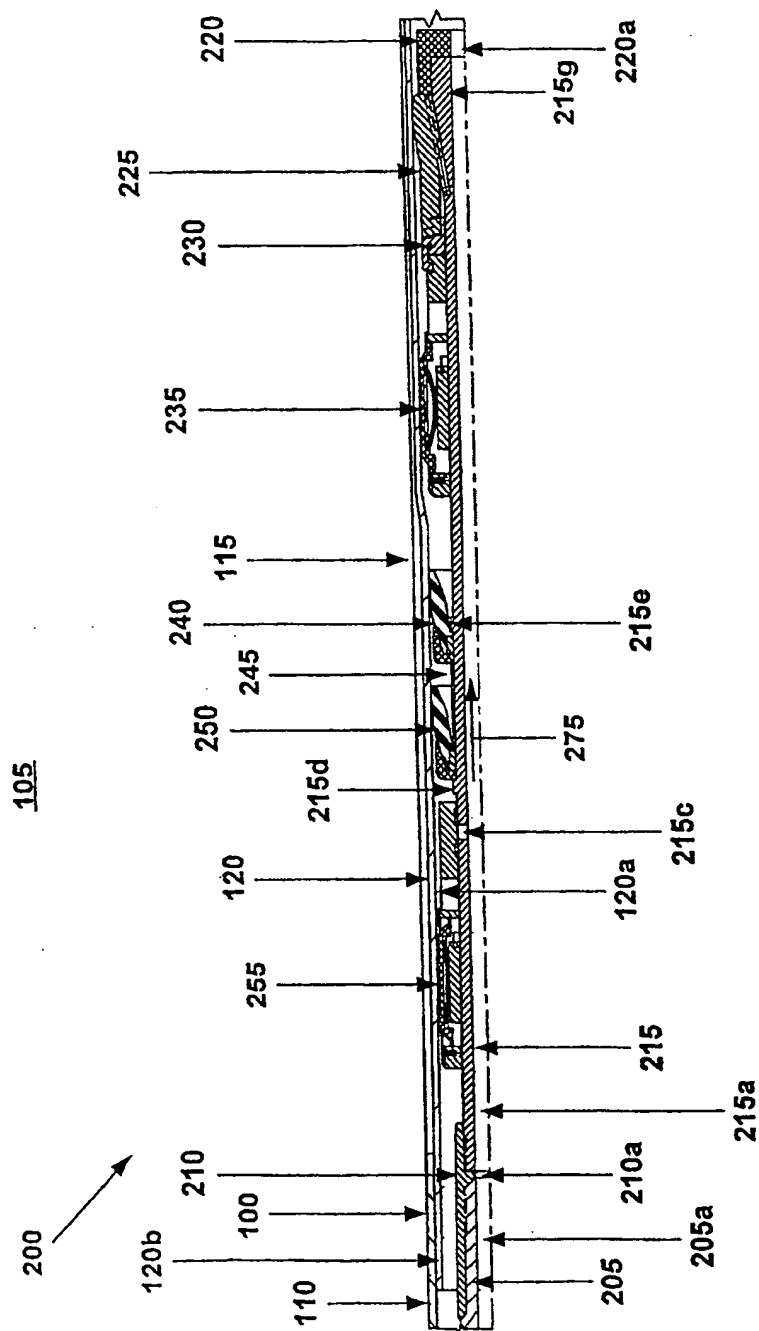


Fig. 2

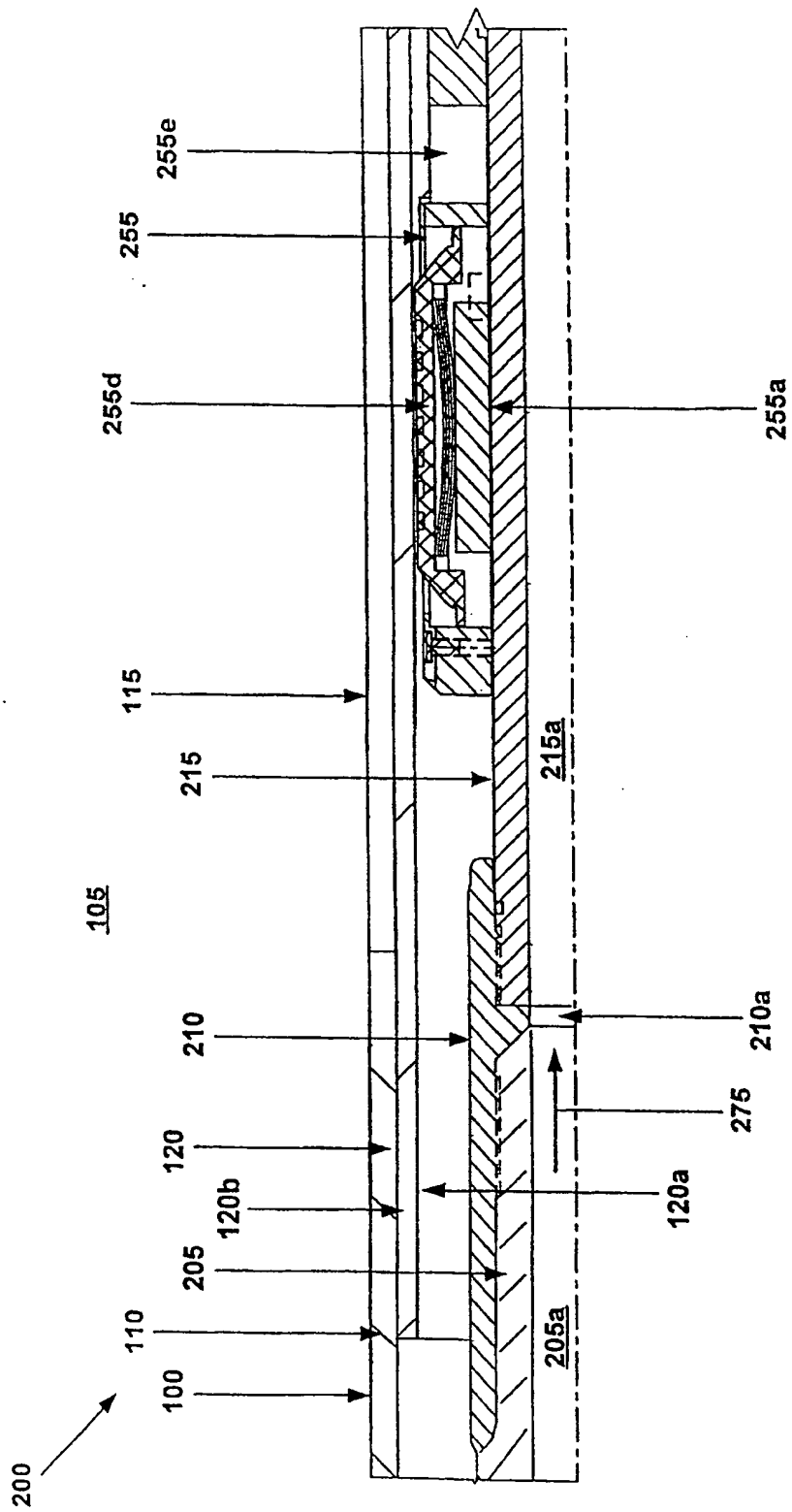


Fig. 2a

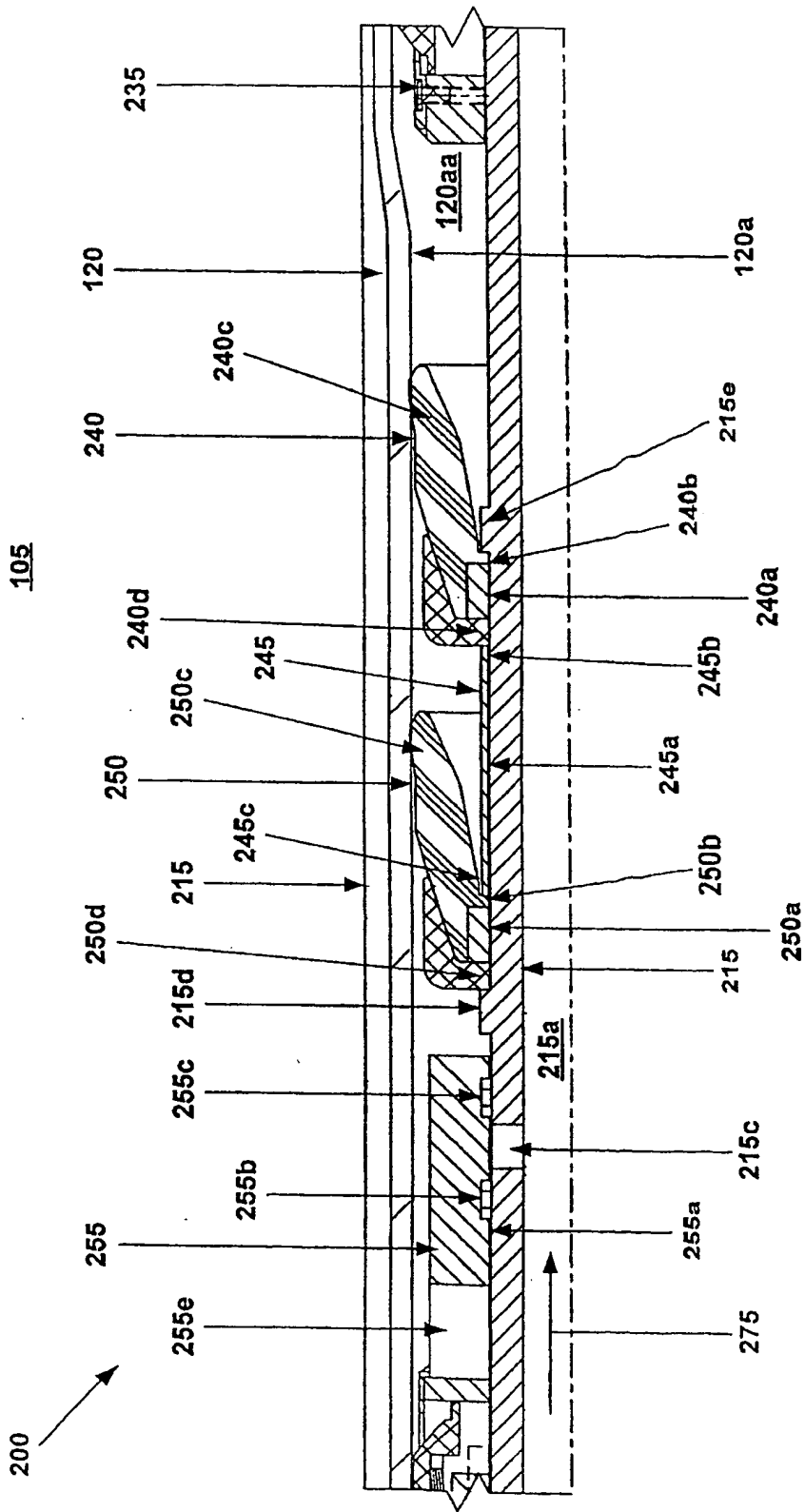


Fig. 2b

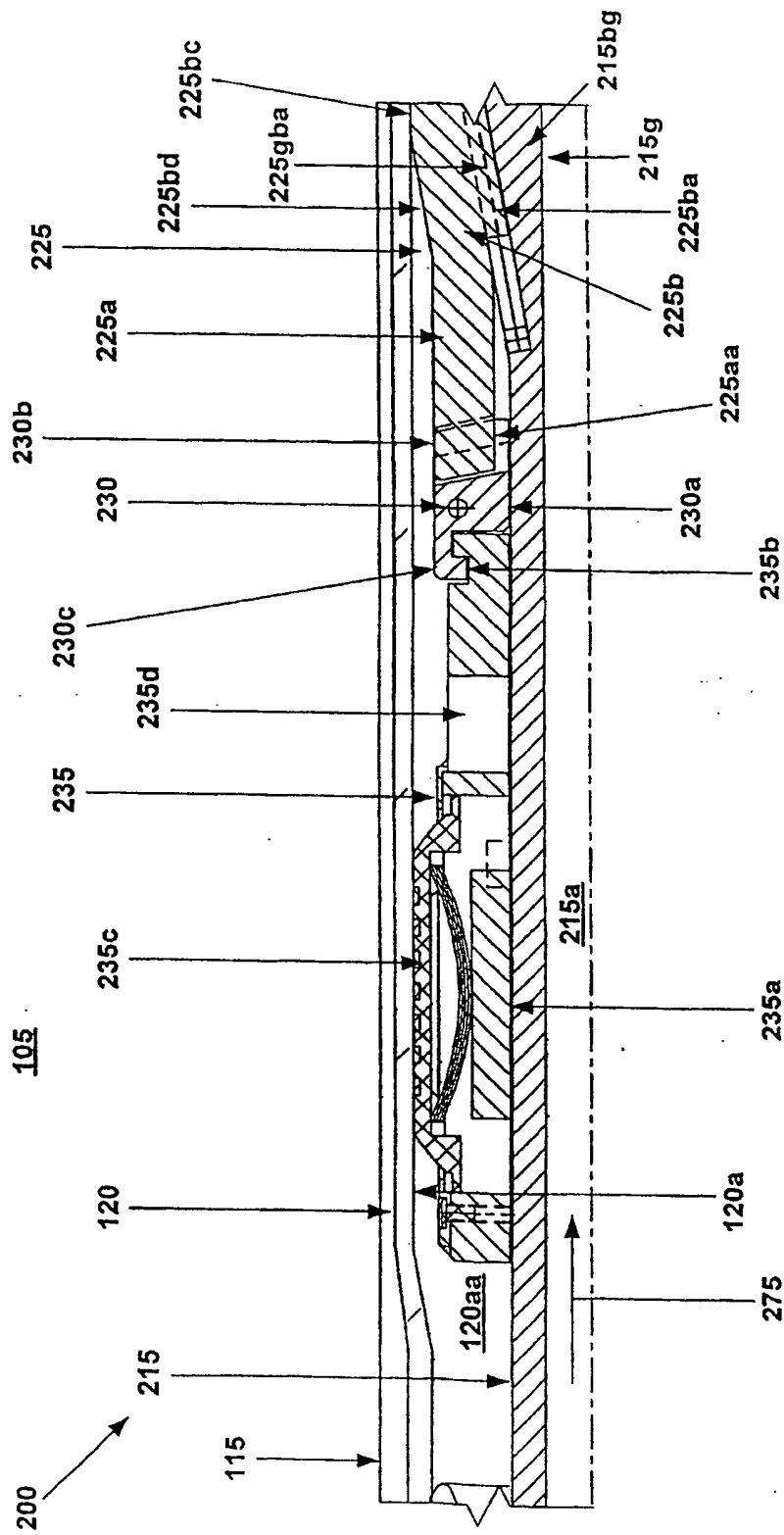


Fig. 2c

200 ↗

105

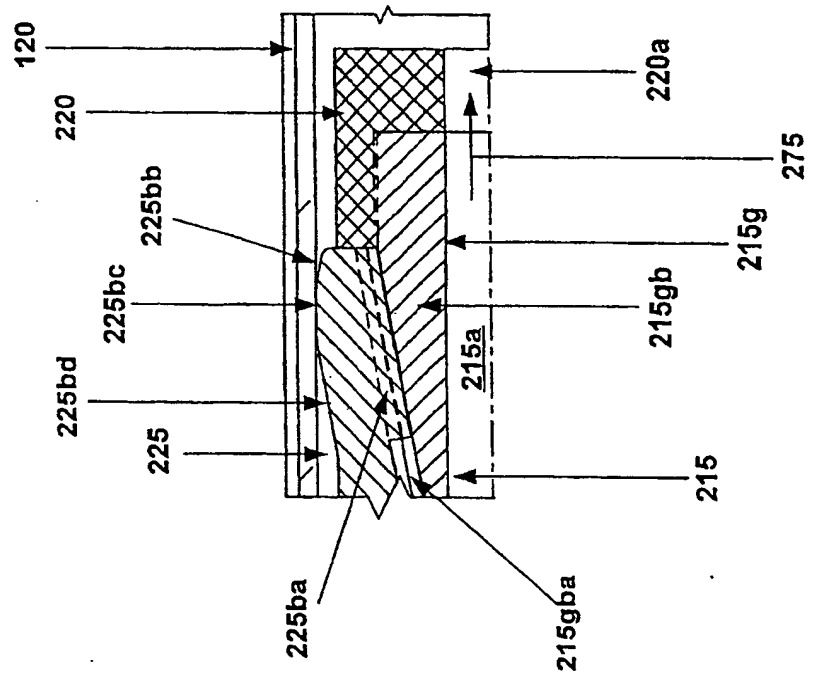
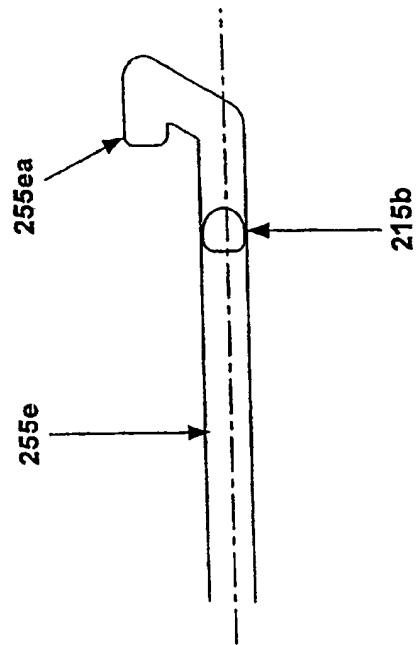
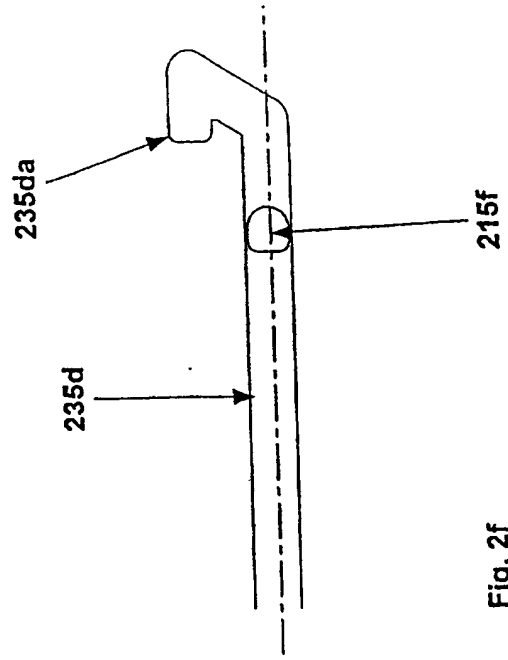


Fig. 2d



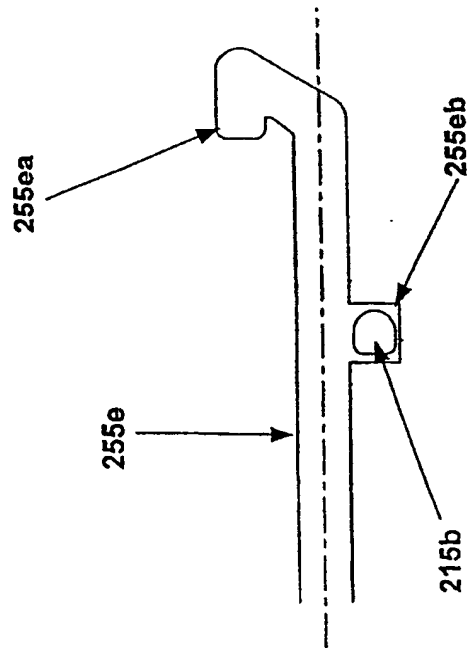


Fig. 2g

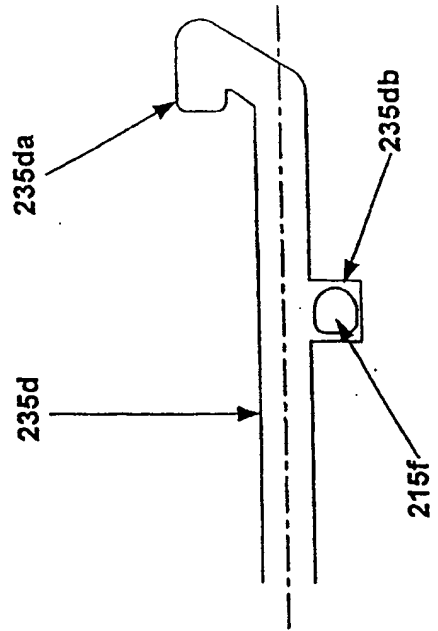


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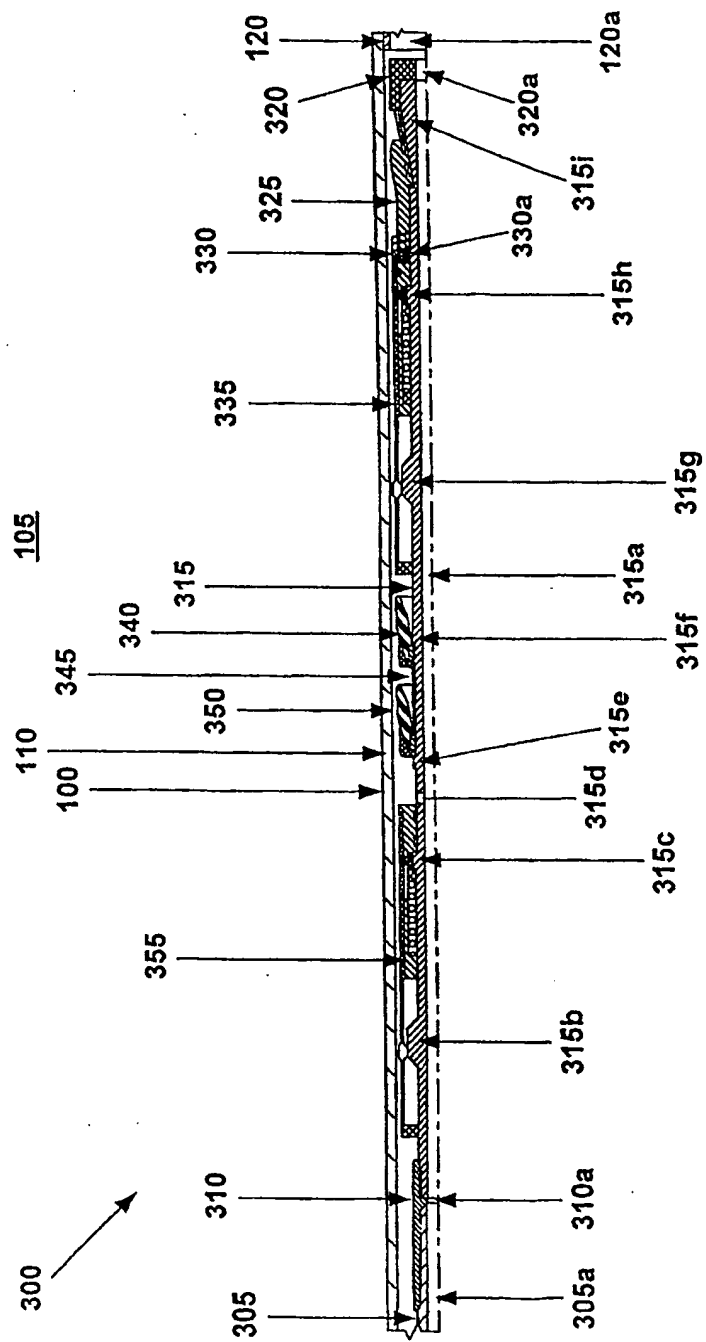


Fig. 3

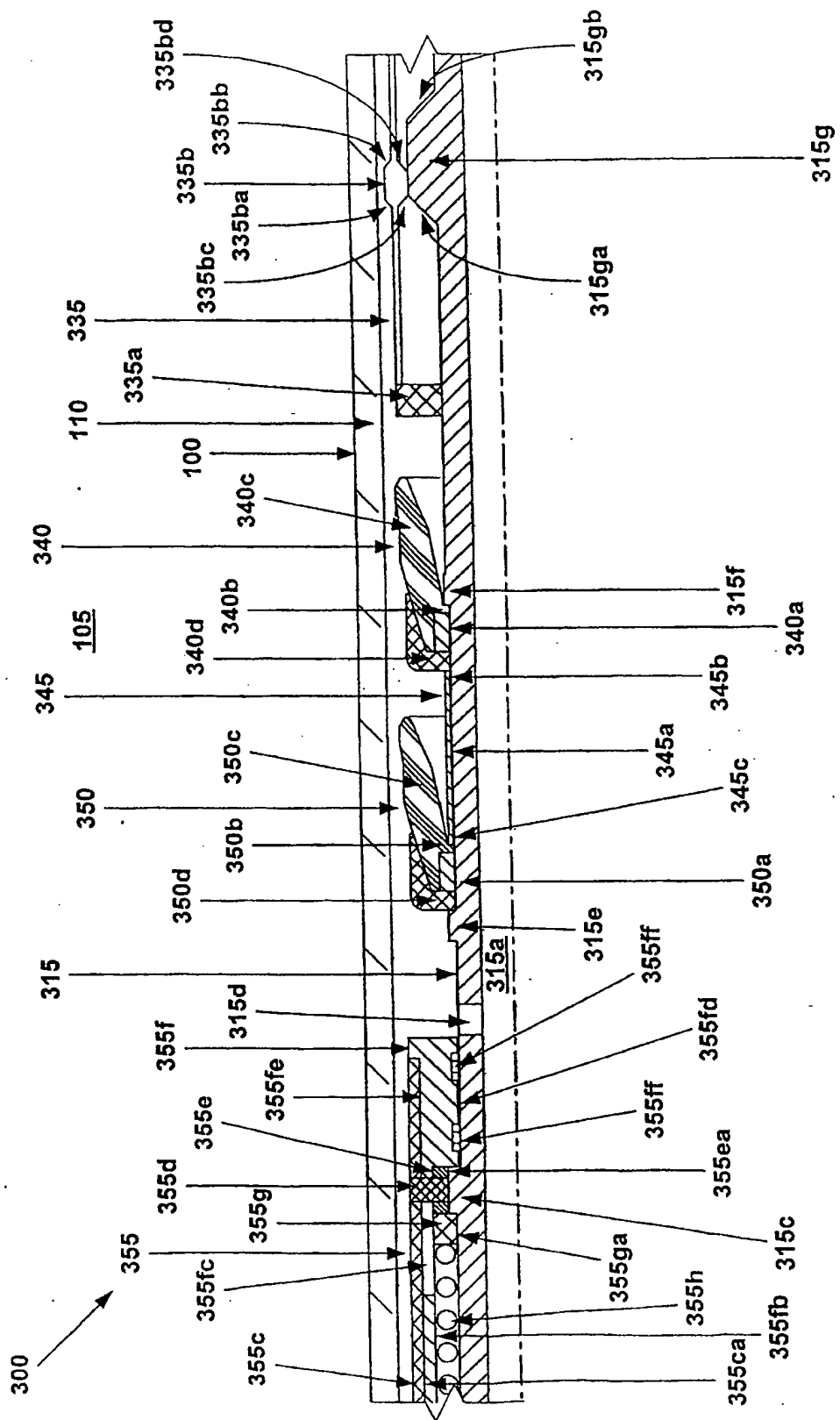
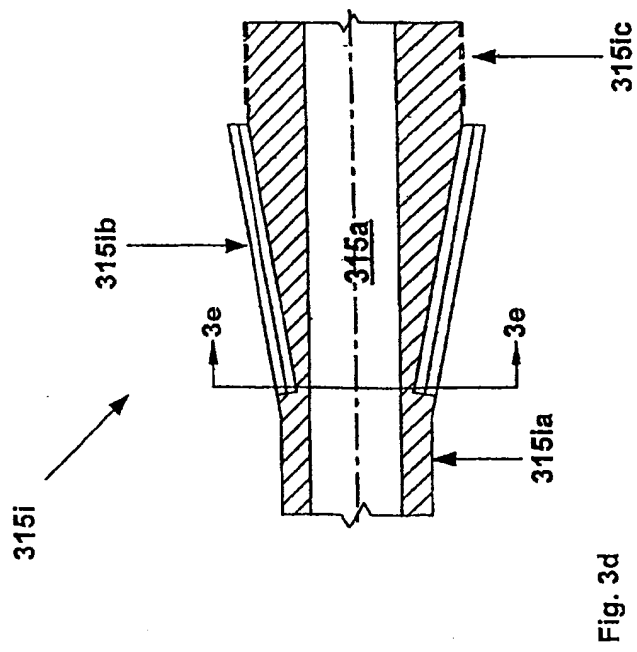
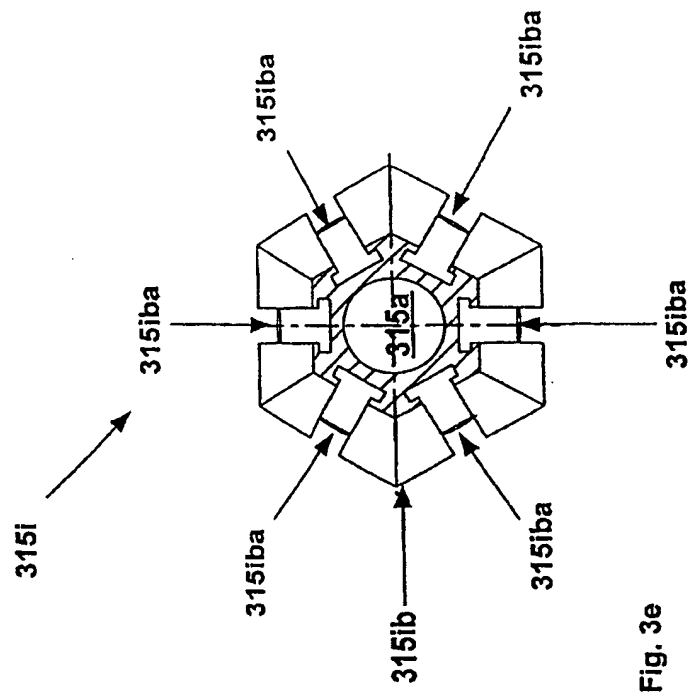


Fig. 3b



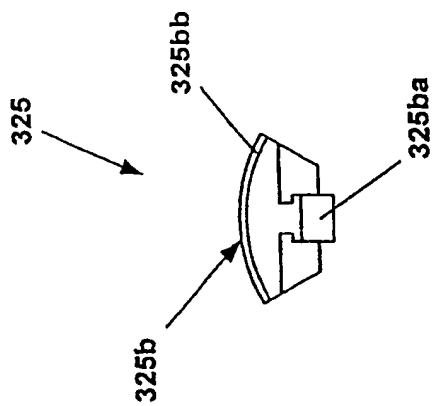


Fig. 3g

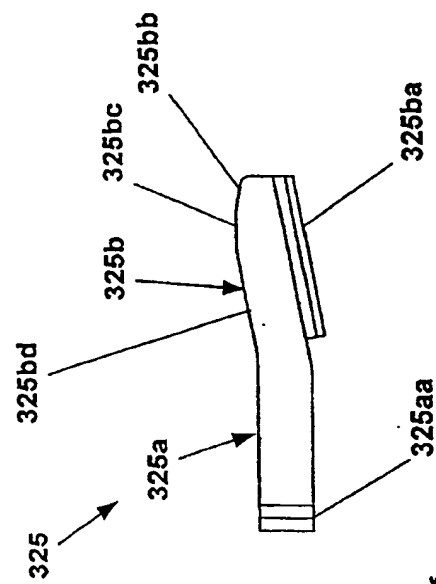


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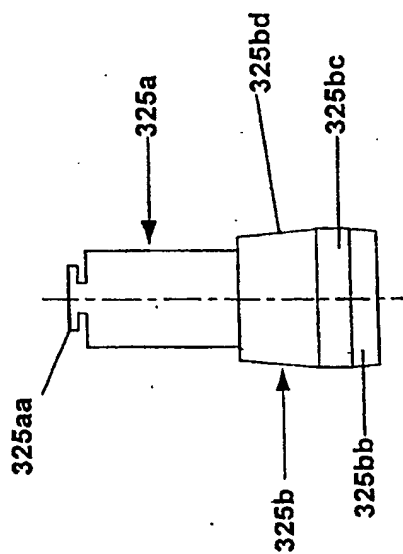


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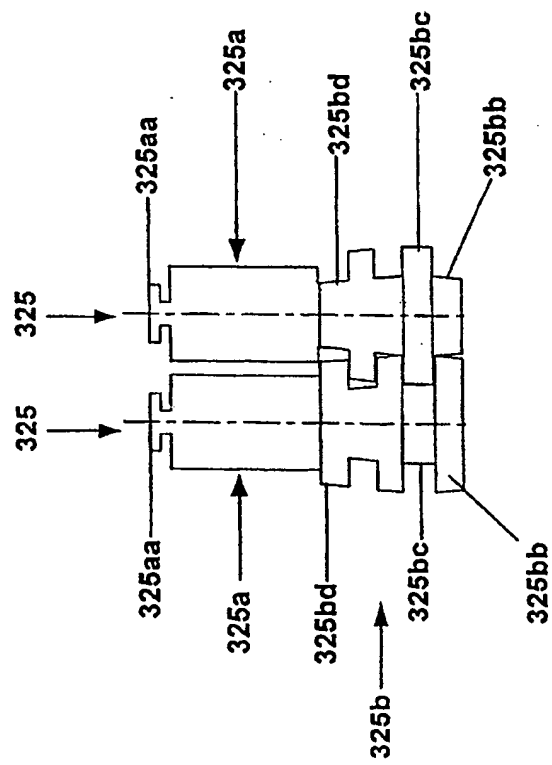


Fig. 3I

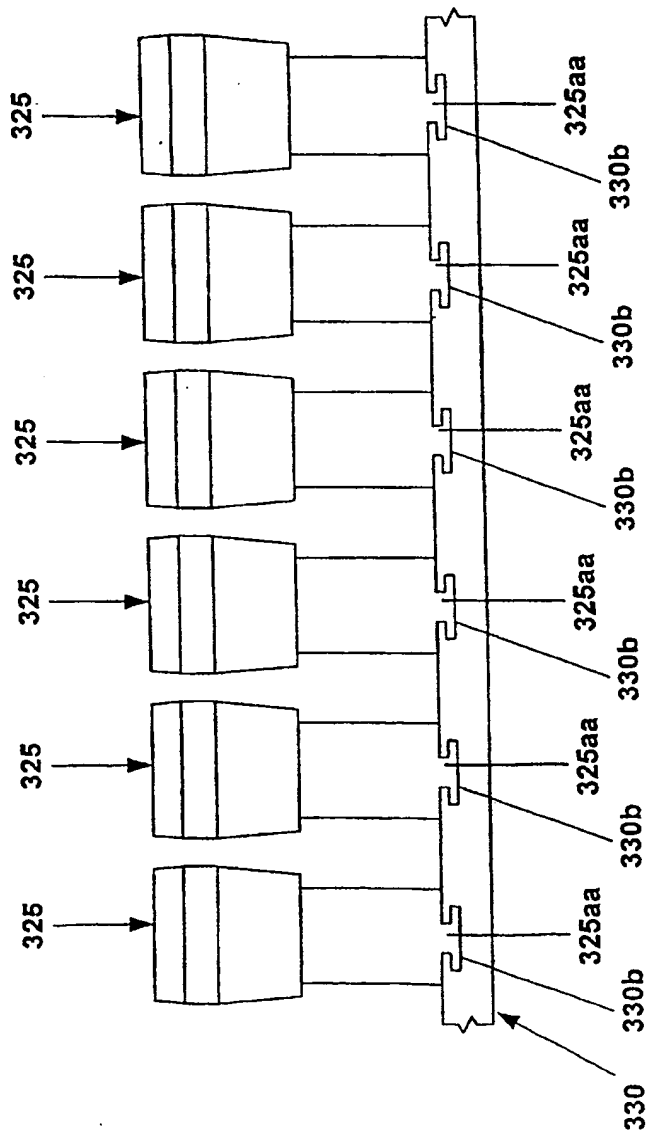


Fig. 3j

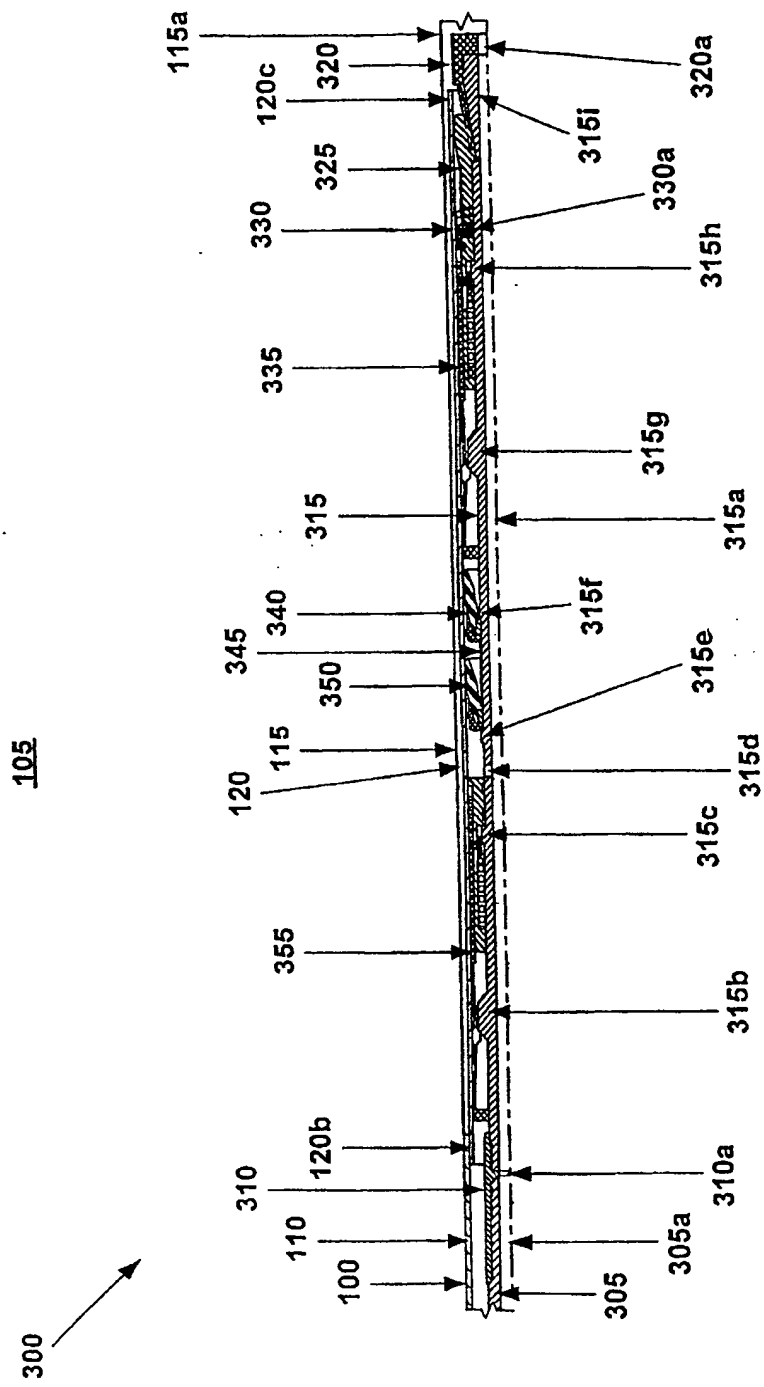


Fig. 4

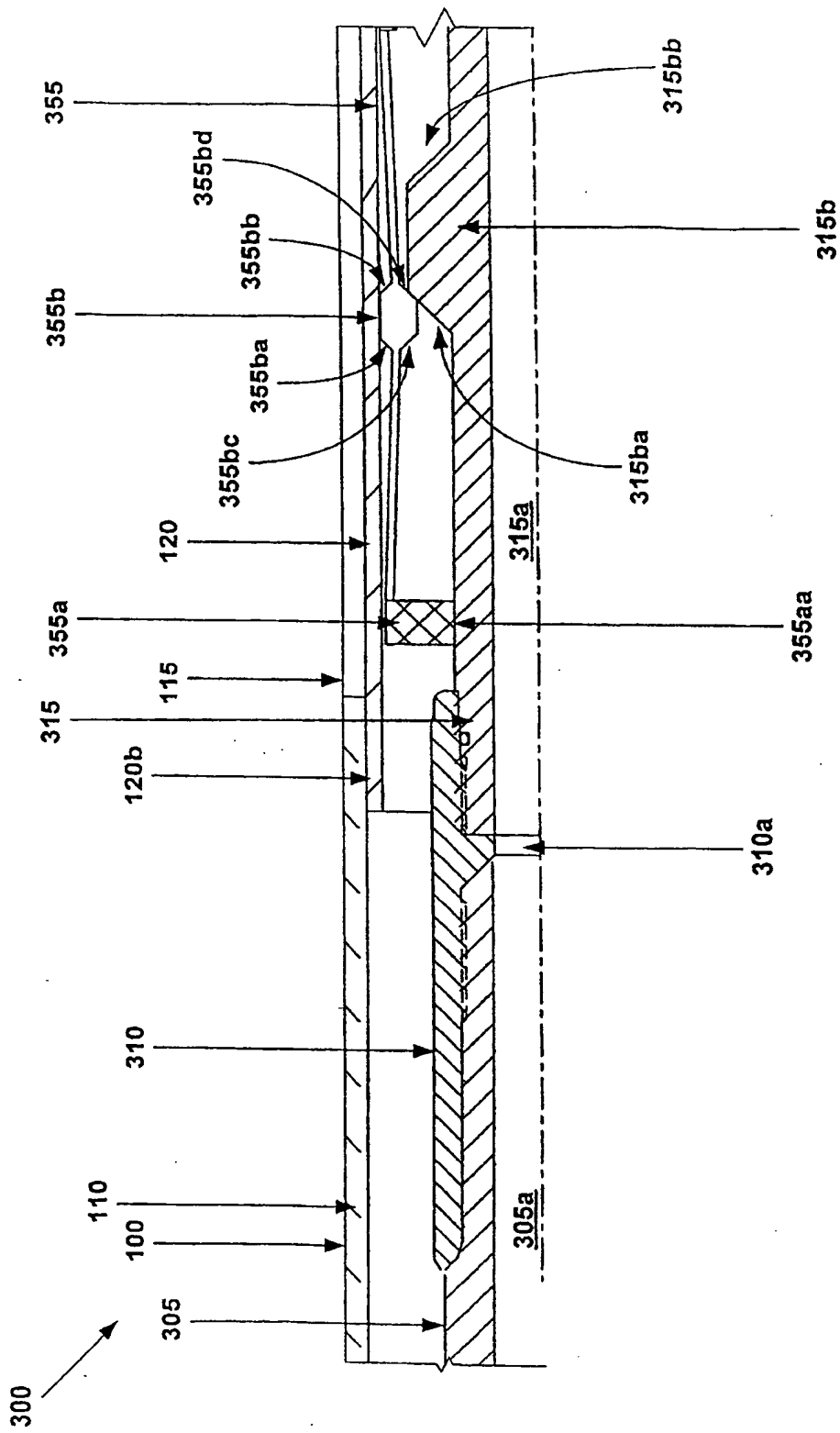


Fig. 4a

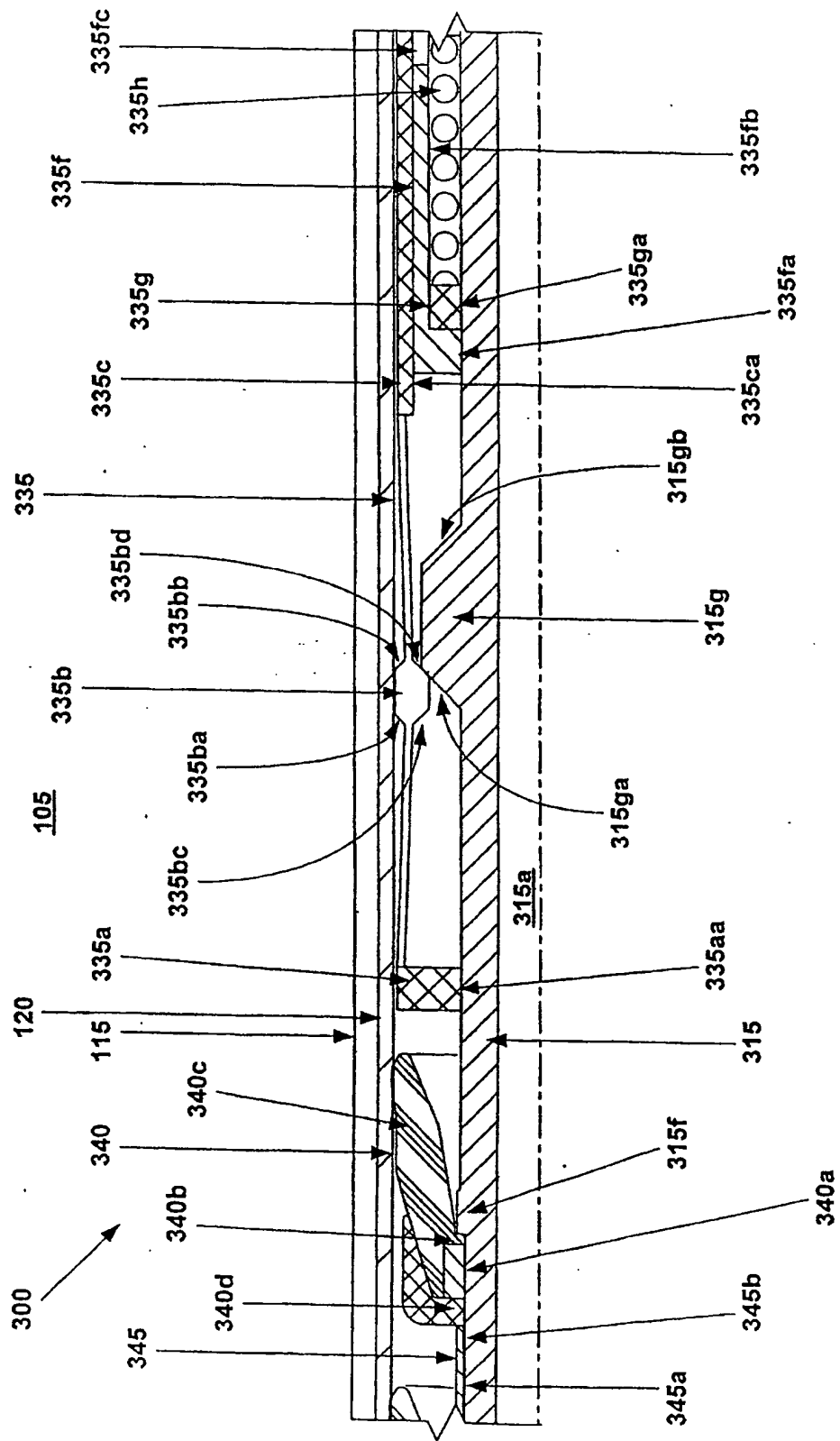


Fig. 4c

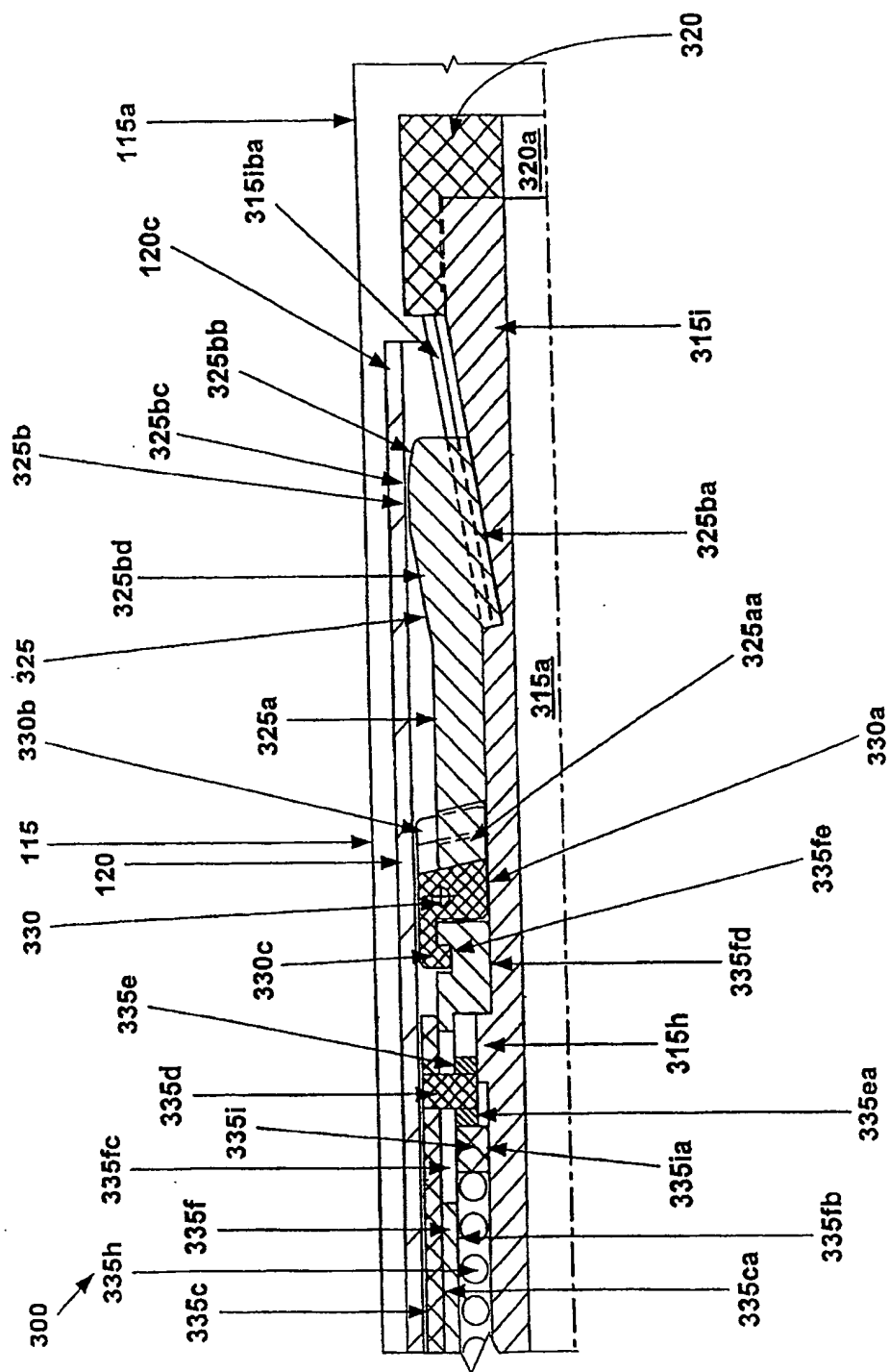


Fig. 4d

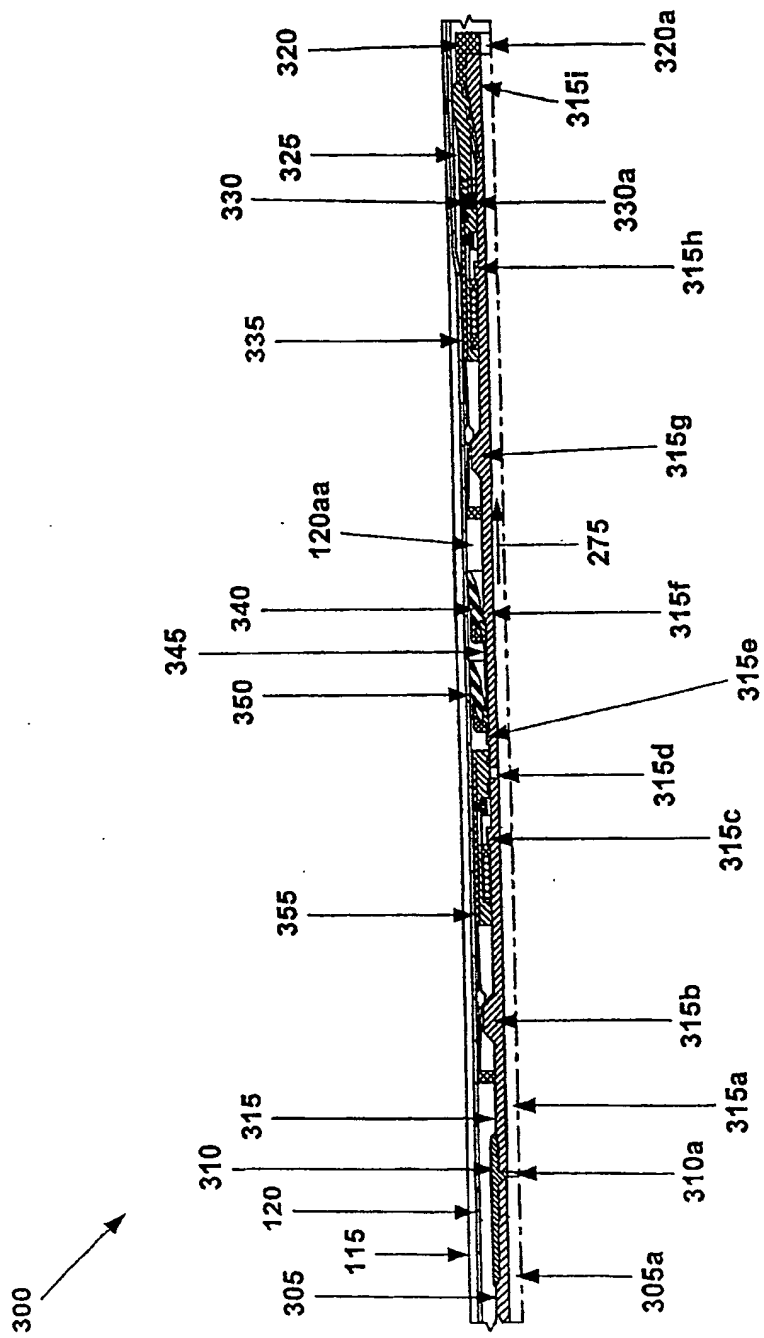


Fig. 5

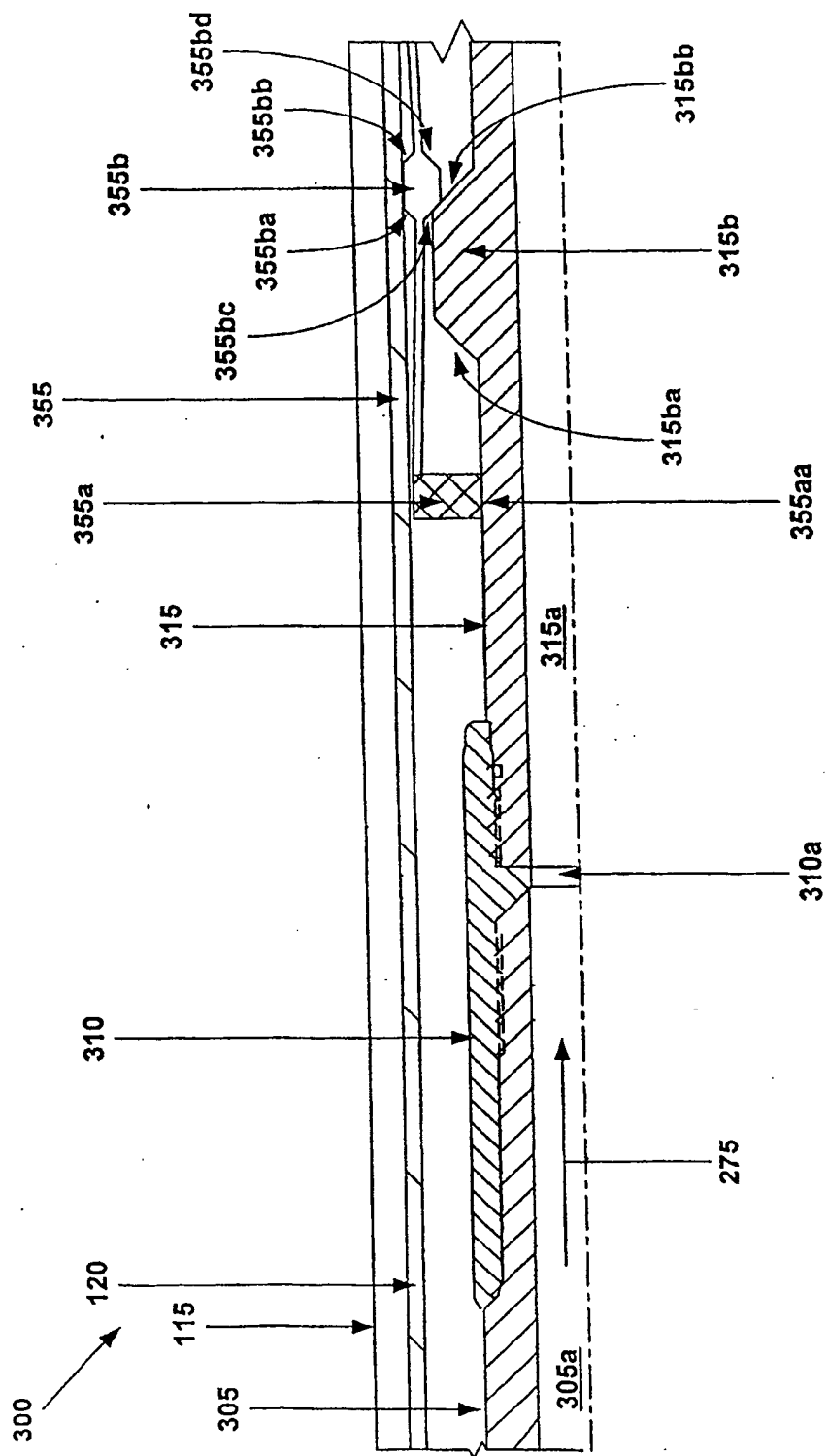


Fig. 5a

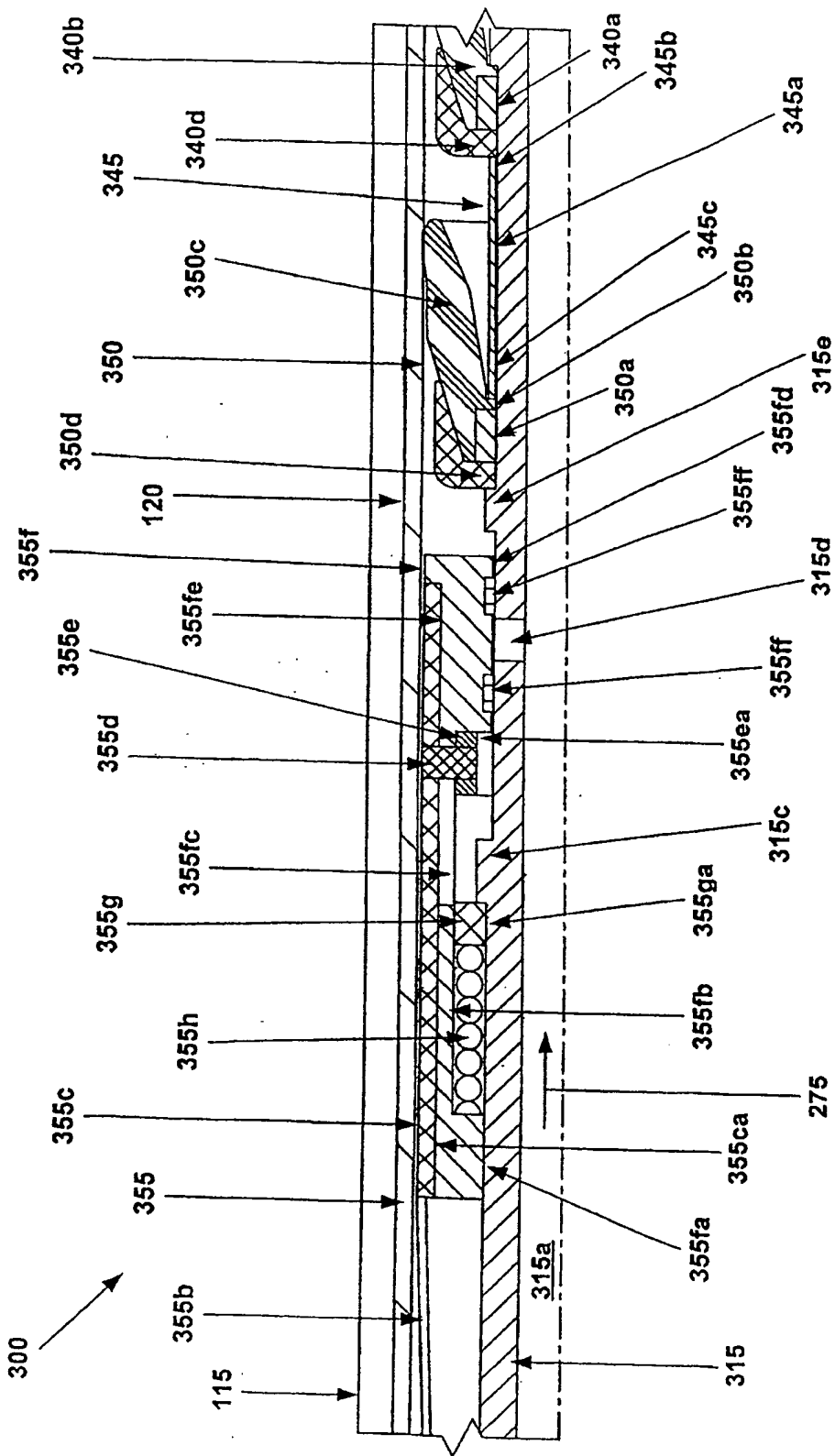


Fig. 5b

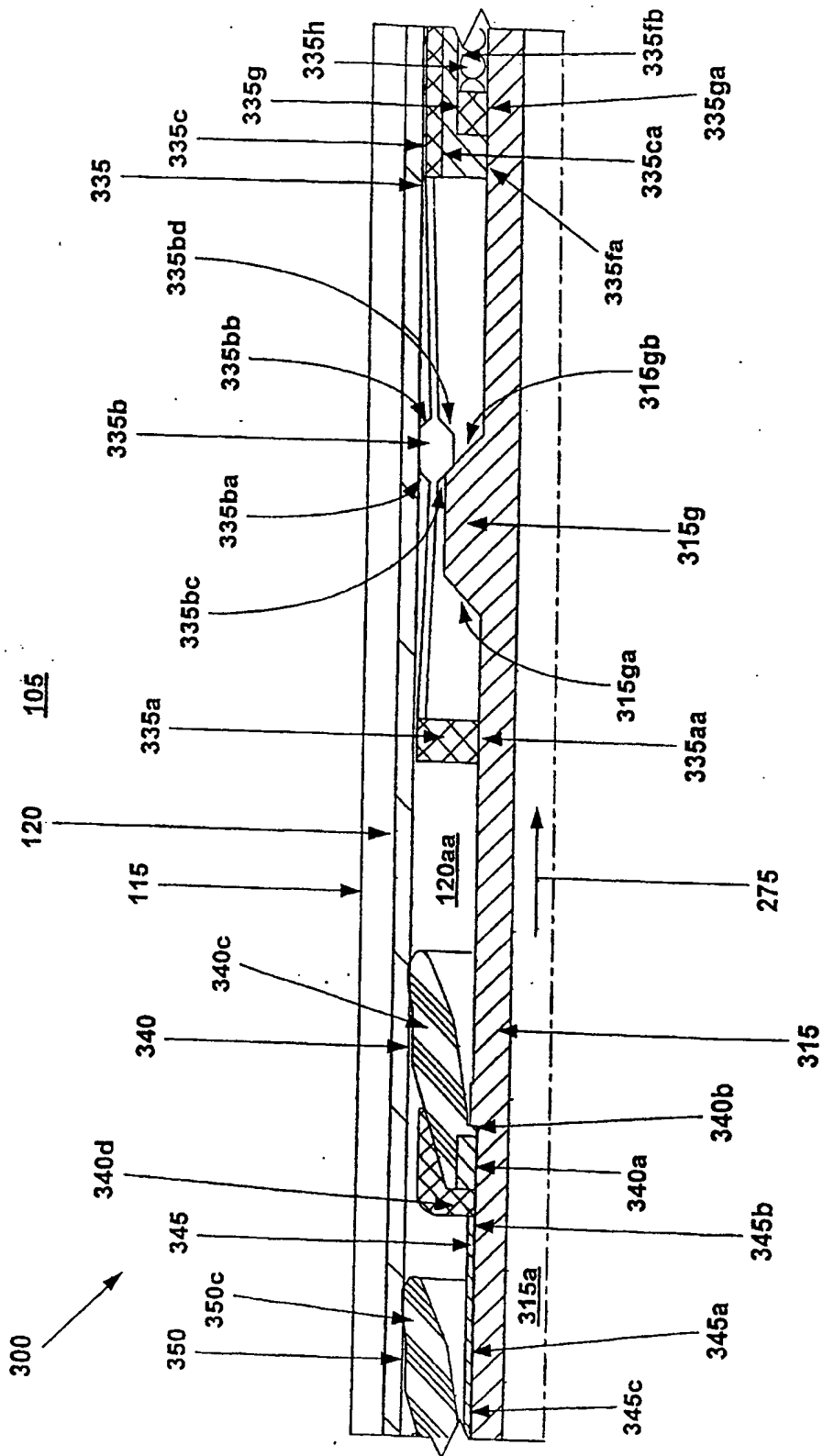


Fig. 5c

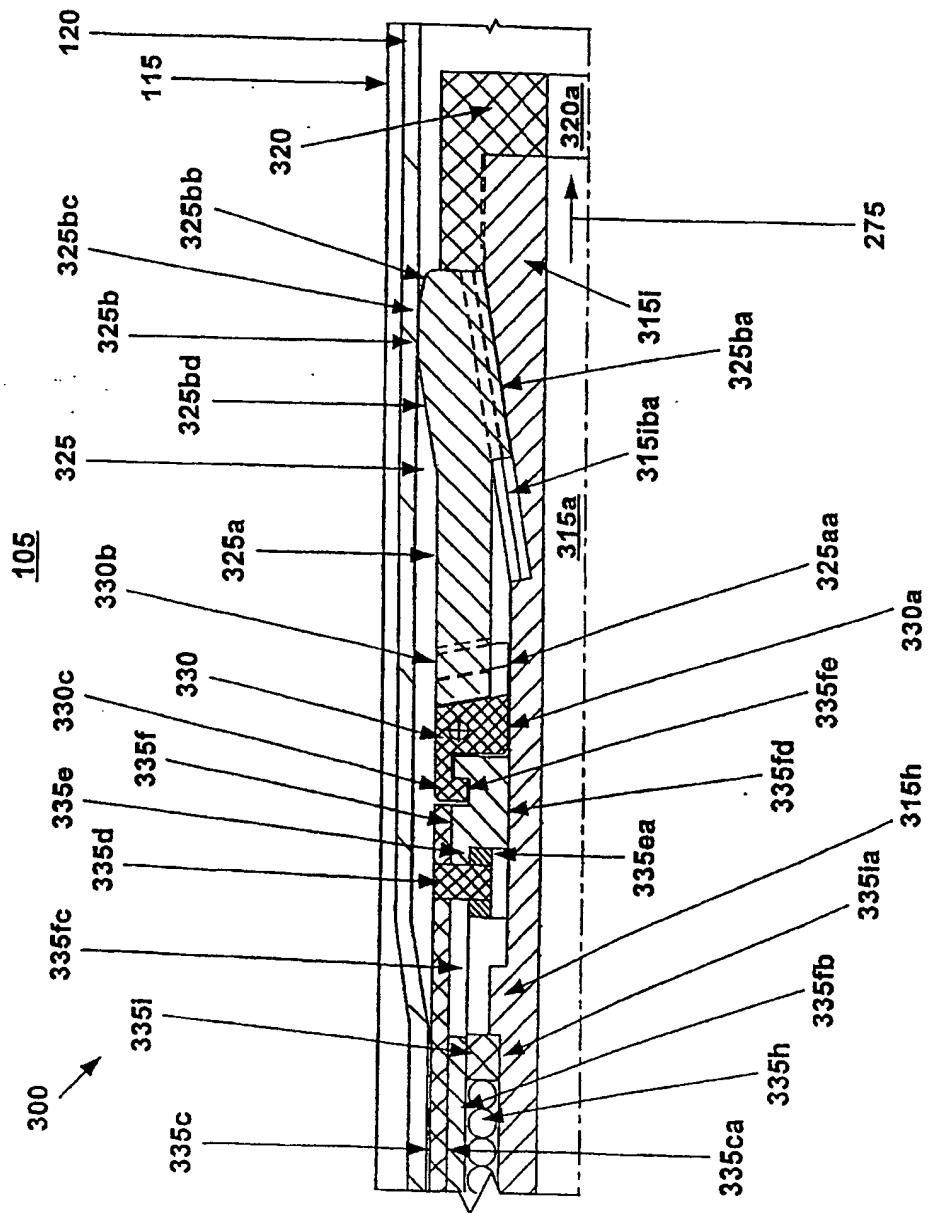


Fig. 5d

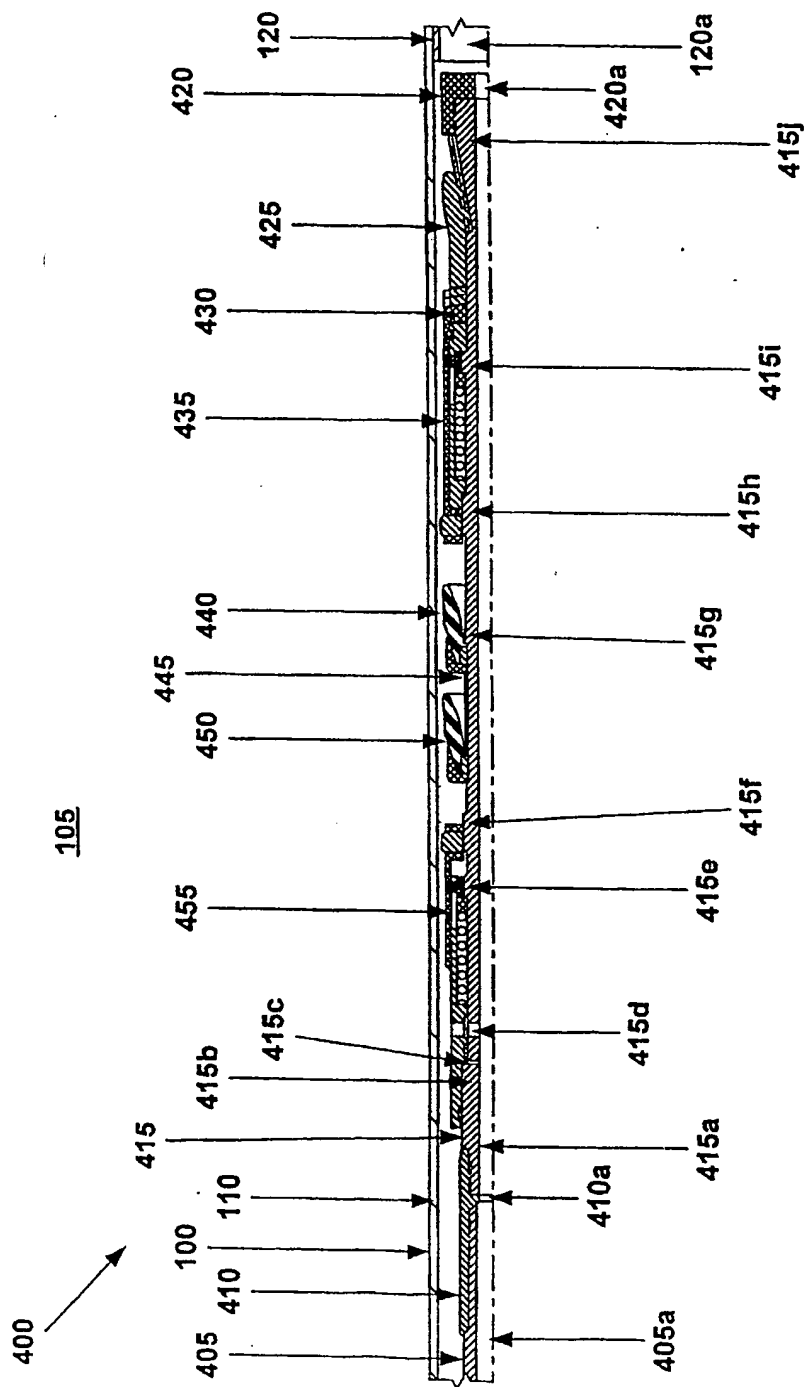


Fig. 6

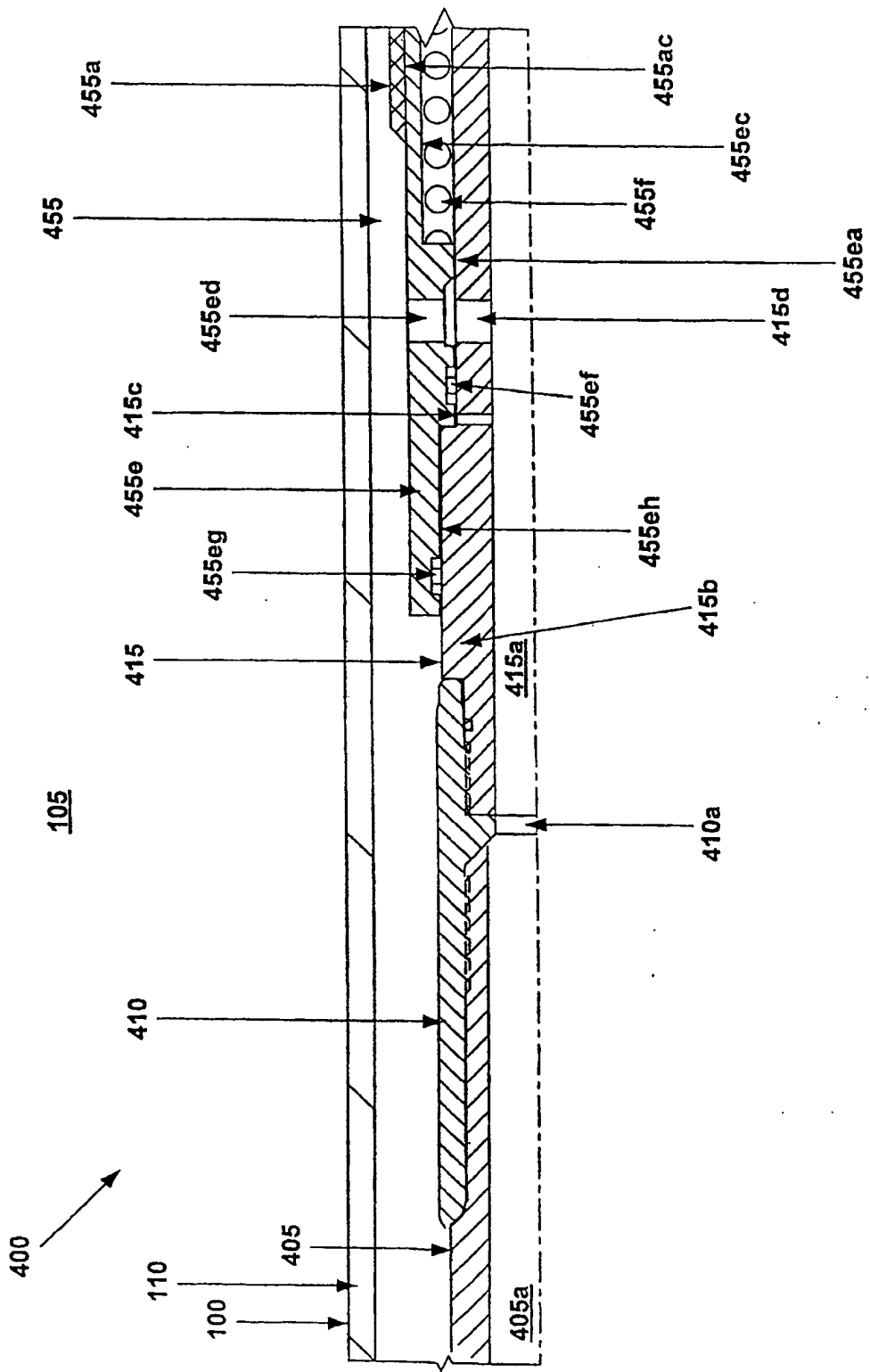


Fig. 6a

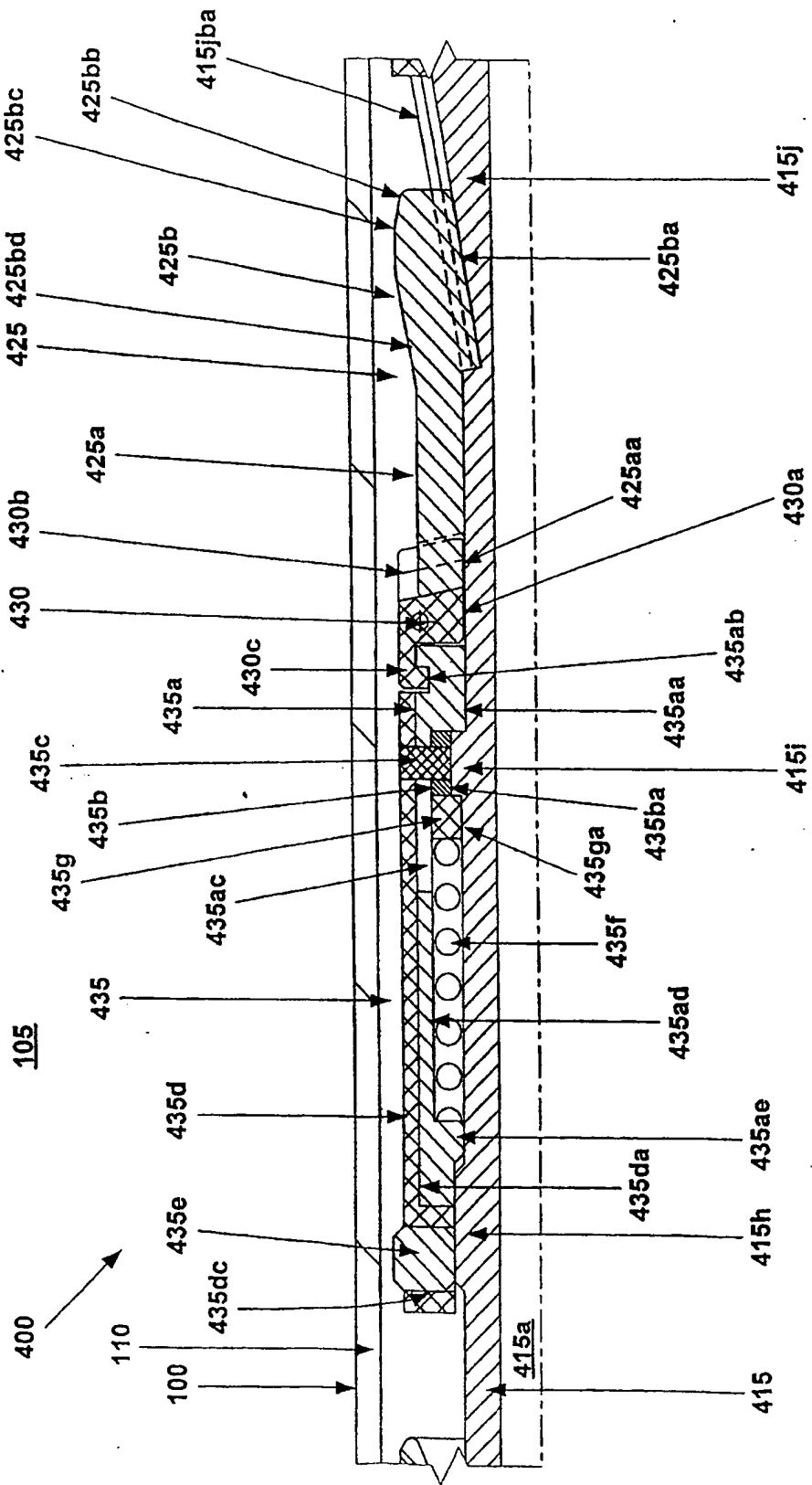


Fig. 6c

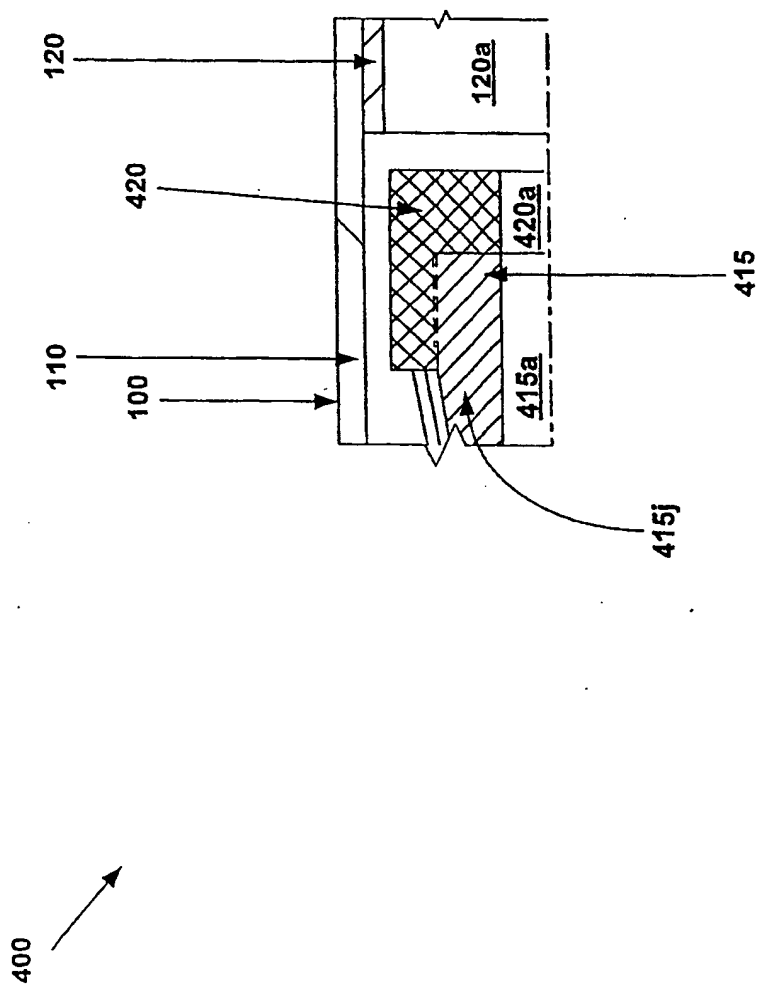
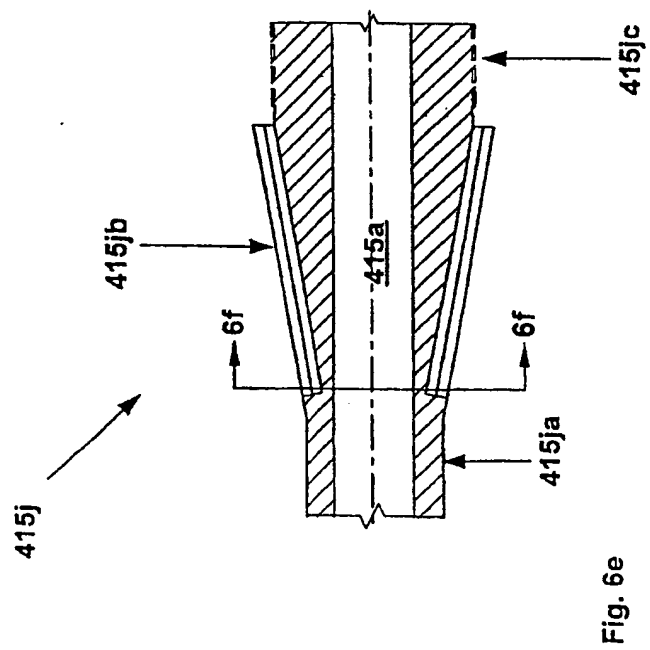
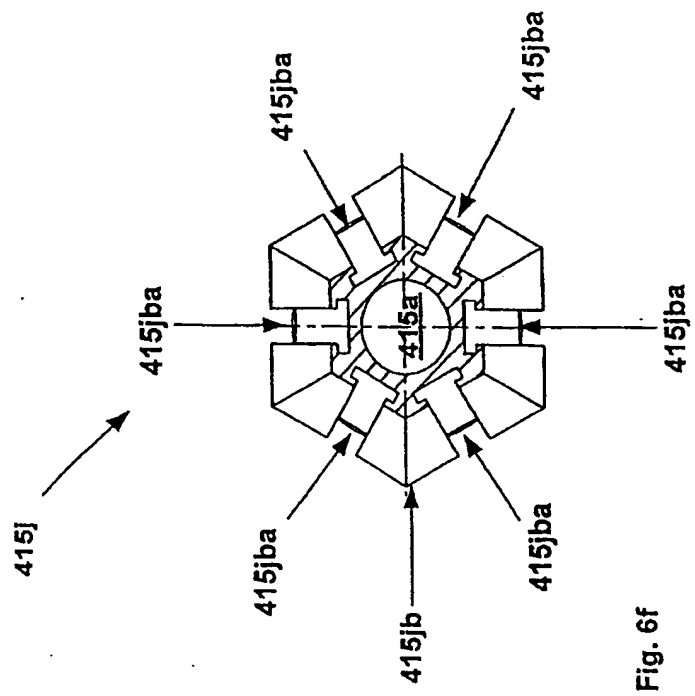


Fig. 6d



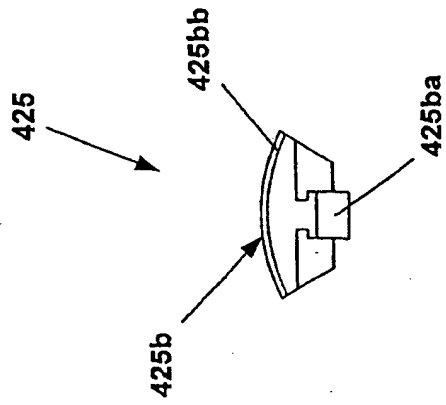


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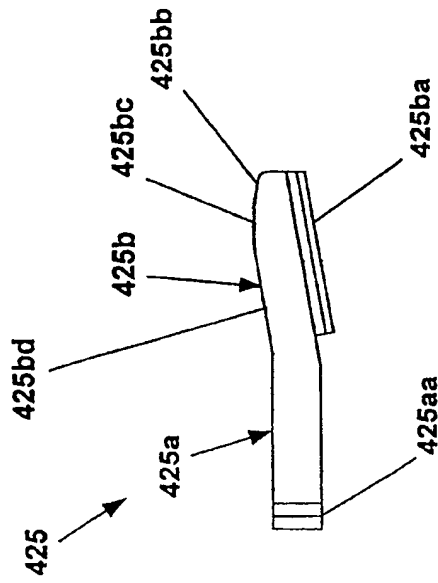


Fig. 6g

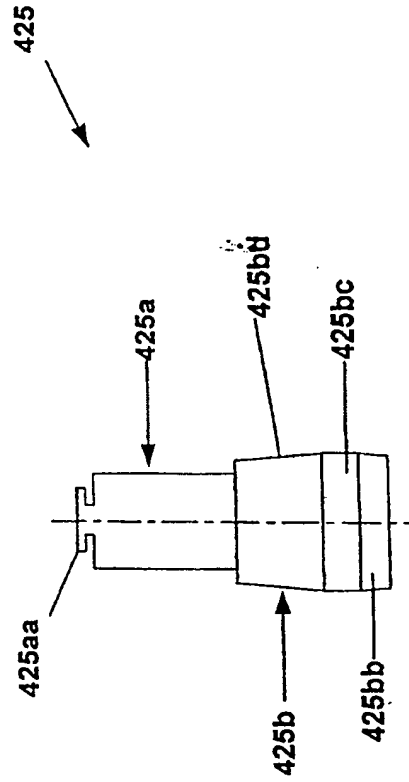


Fig. 6i

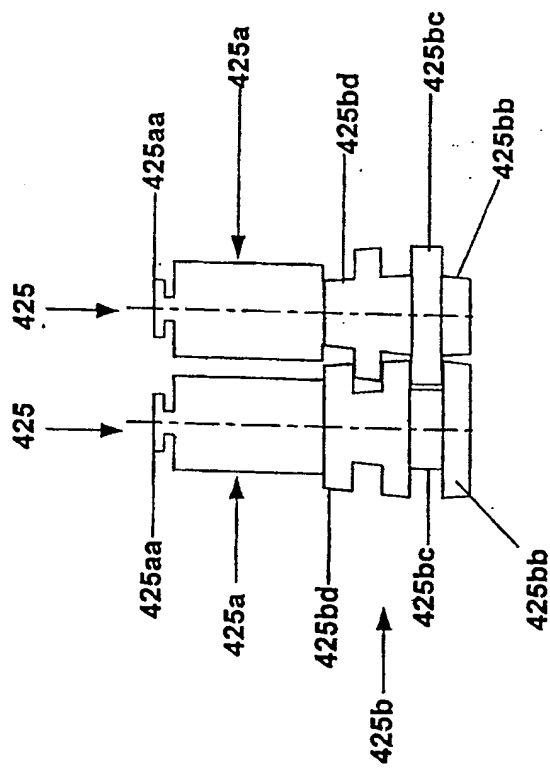


Fig. 6j

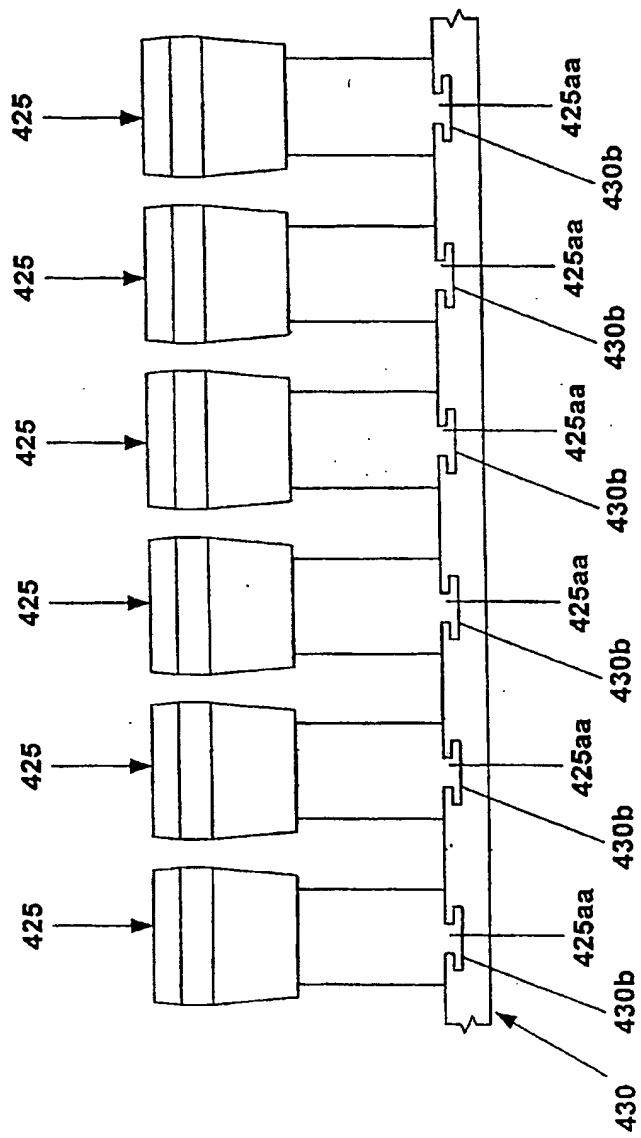


Fig. 6k

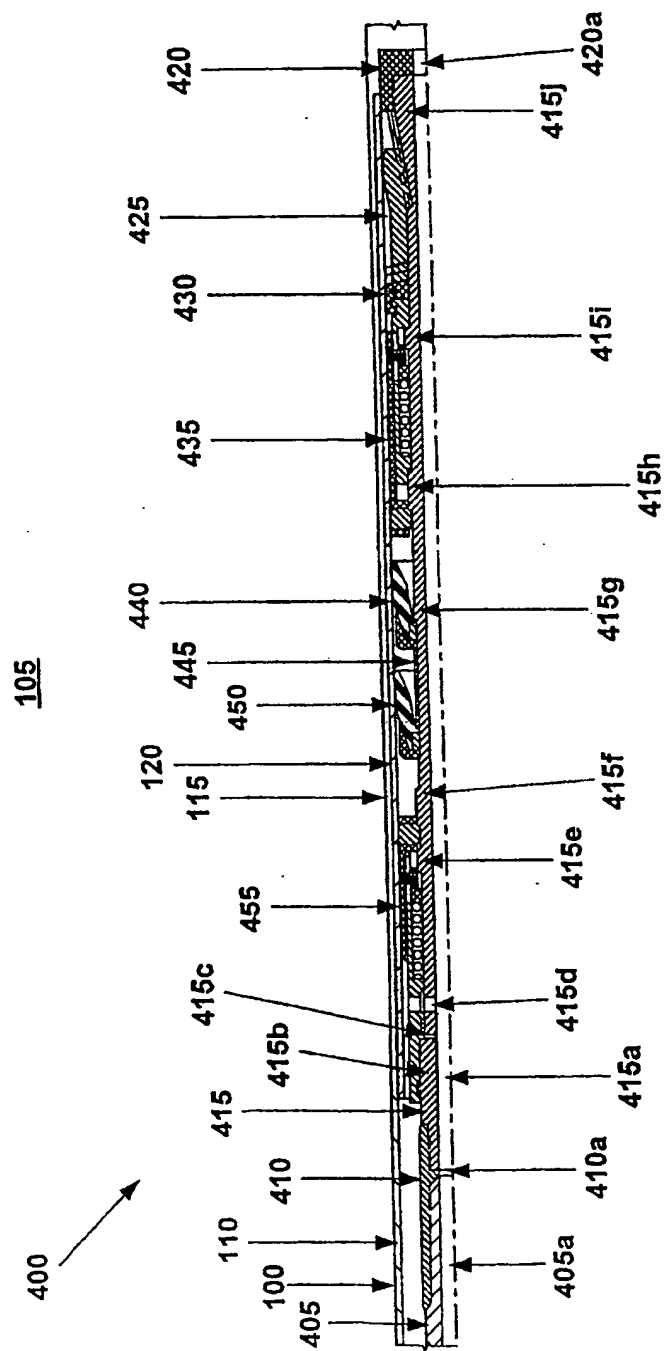


Fig. 7

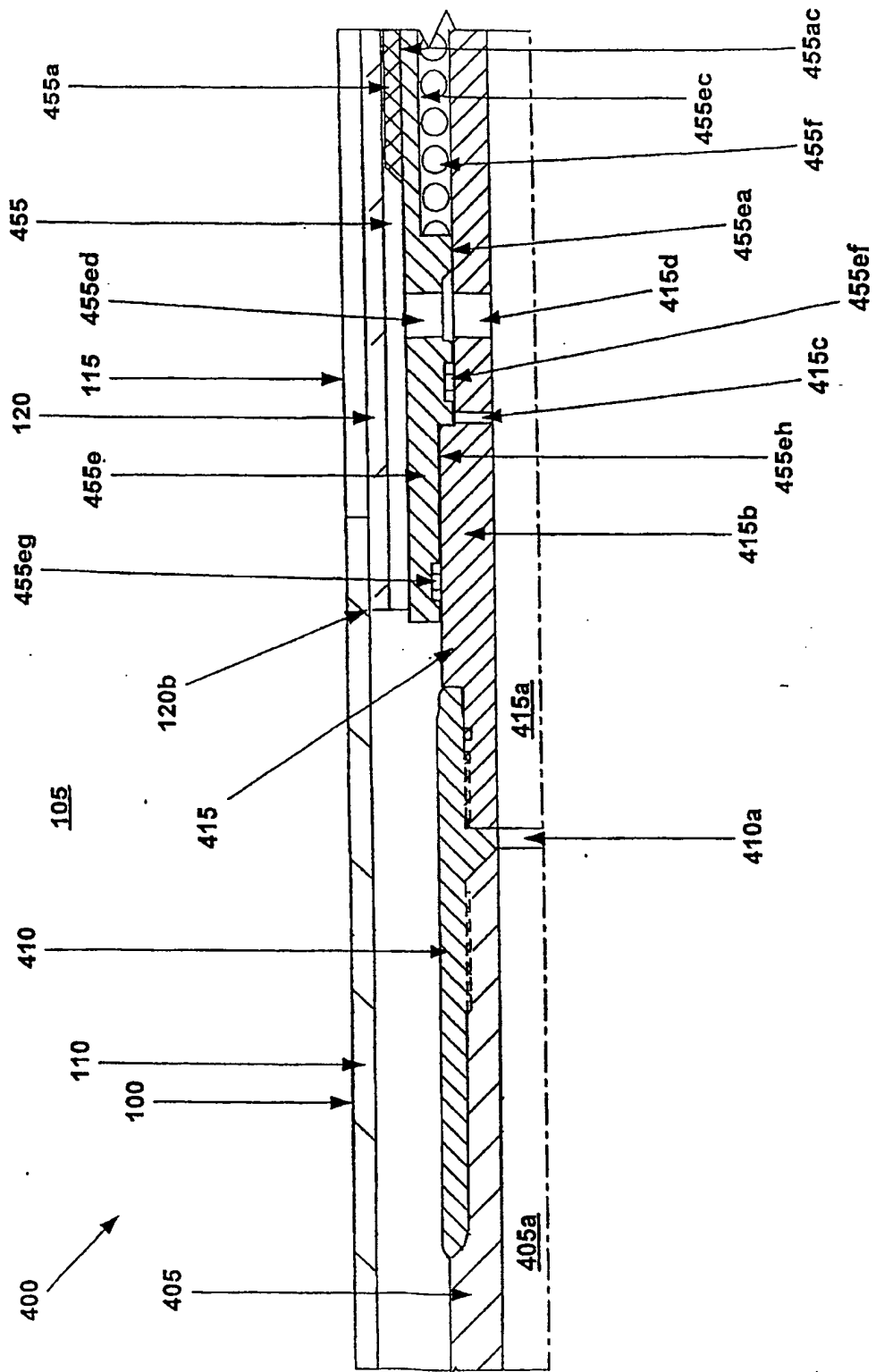


Fig. 7a

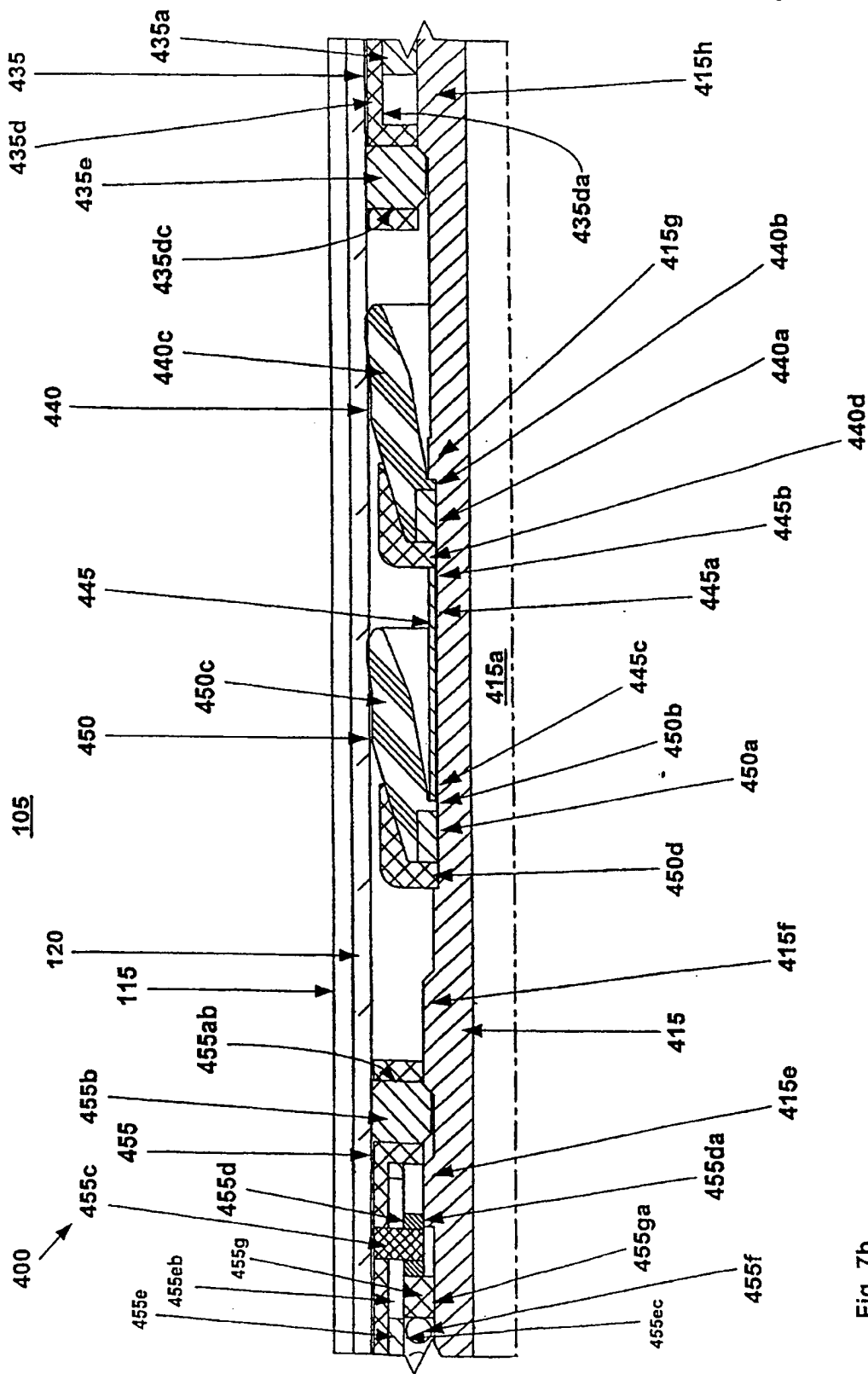


Fig. 7b

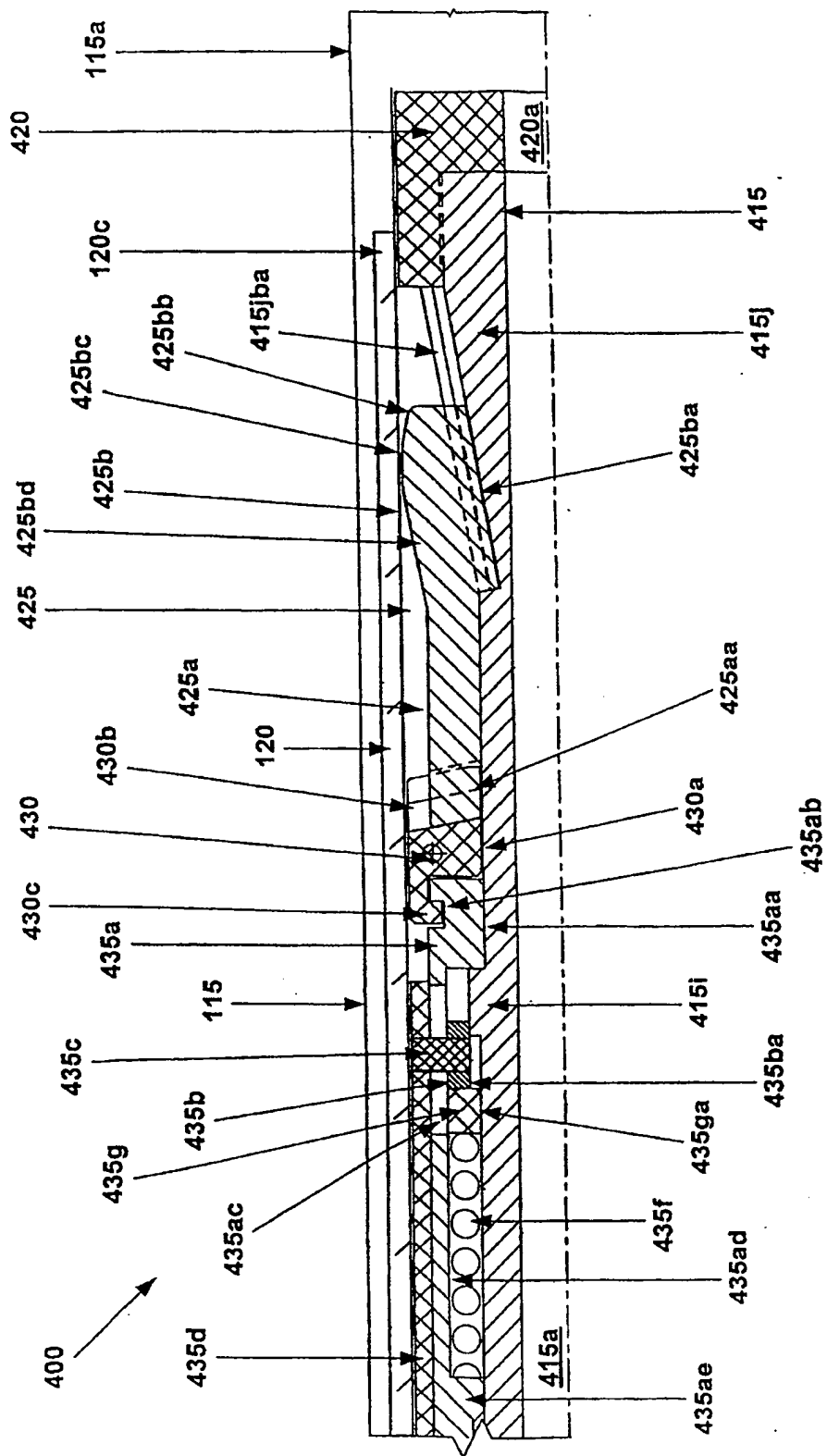


Fig. 7c

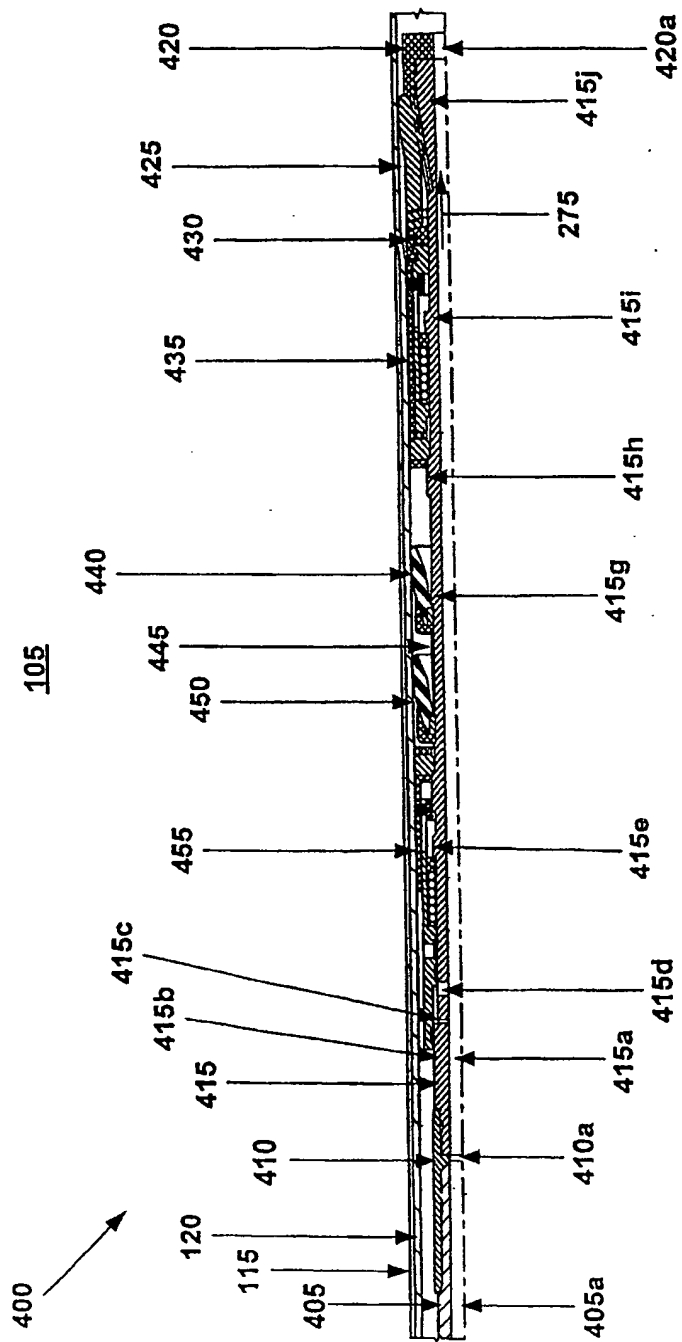


Fig. 8

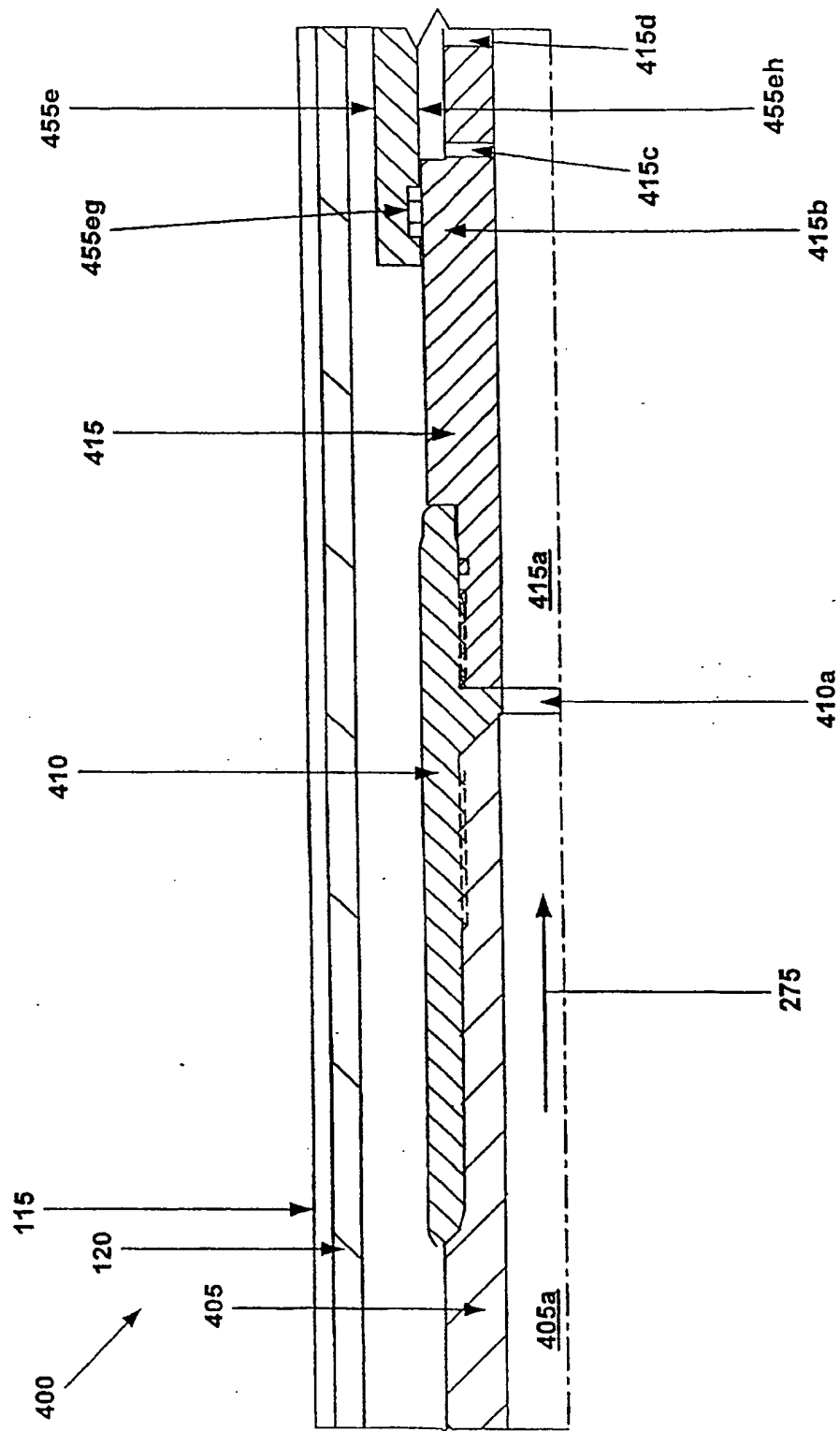


Fig. 8a

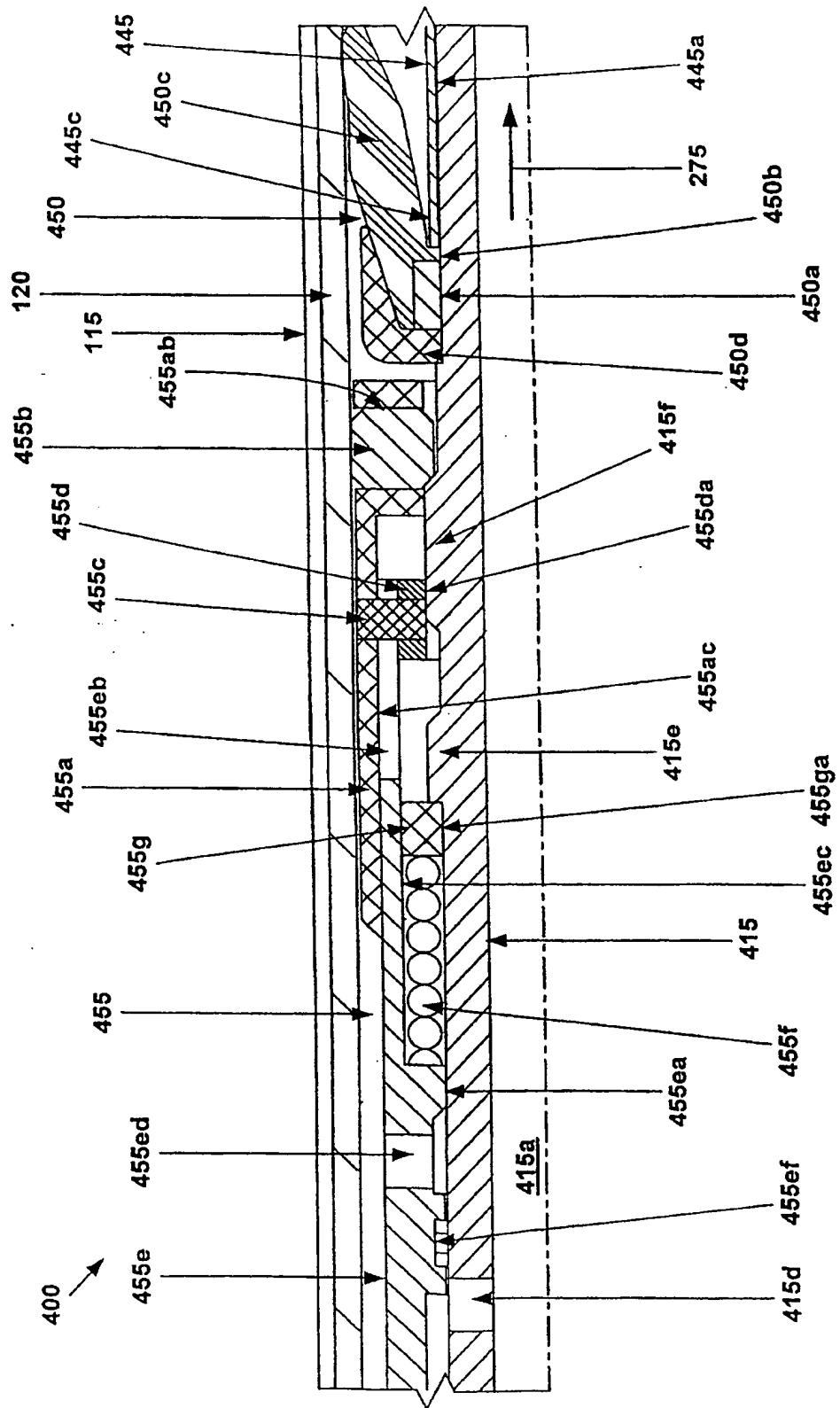


Fig. 8b

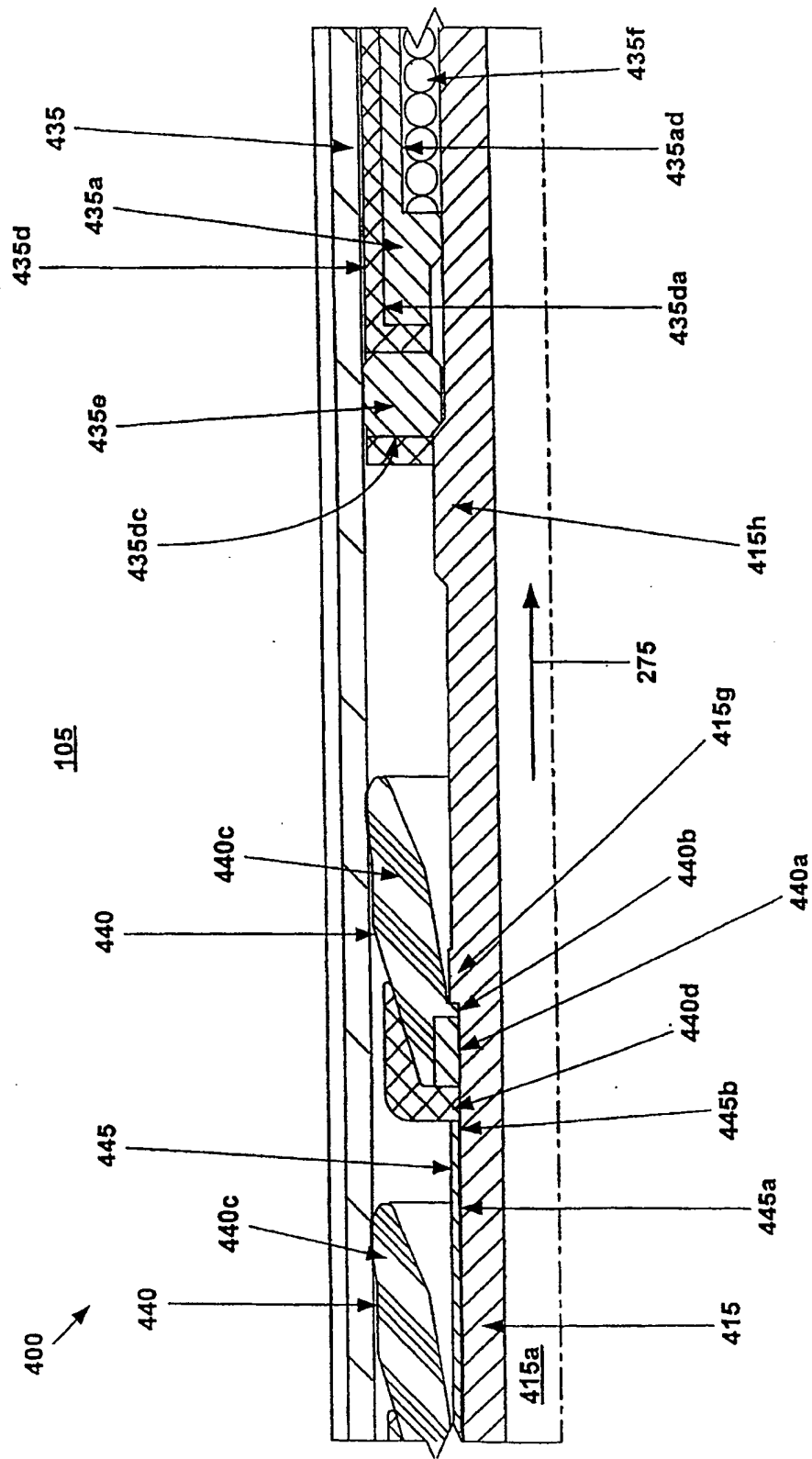


Fig. 8c

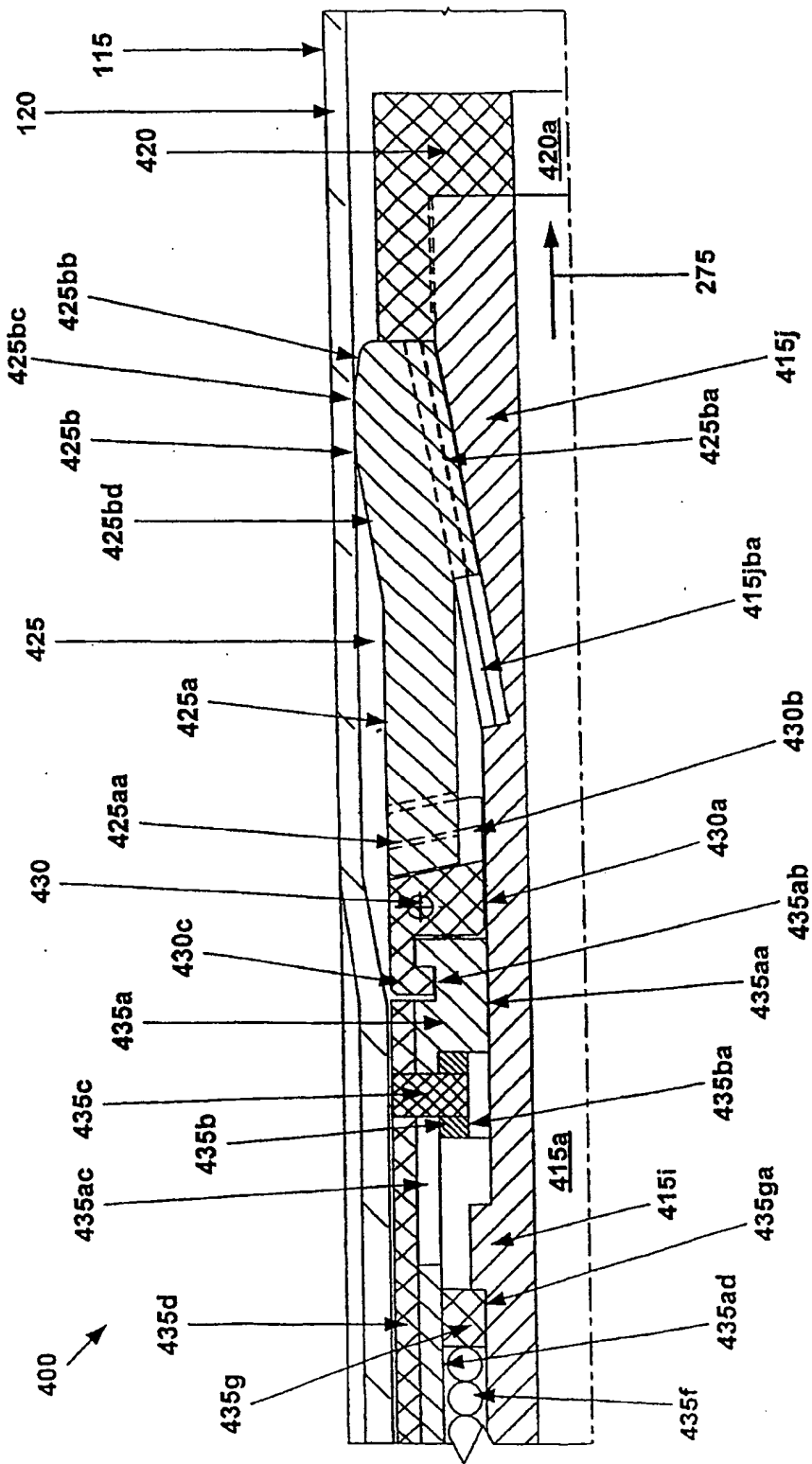


Fig. 8d

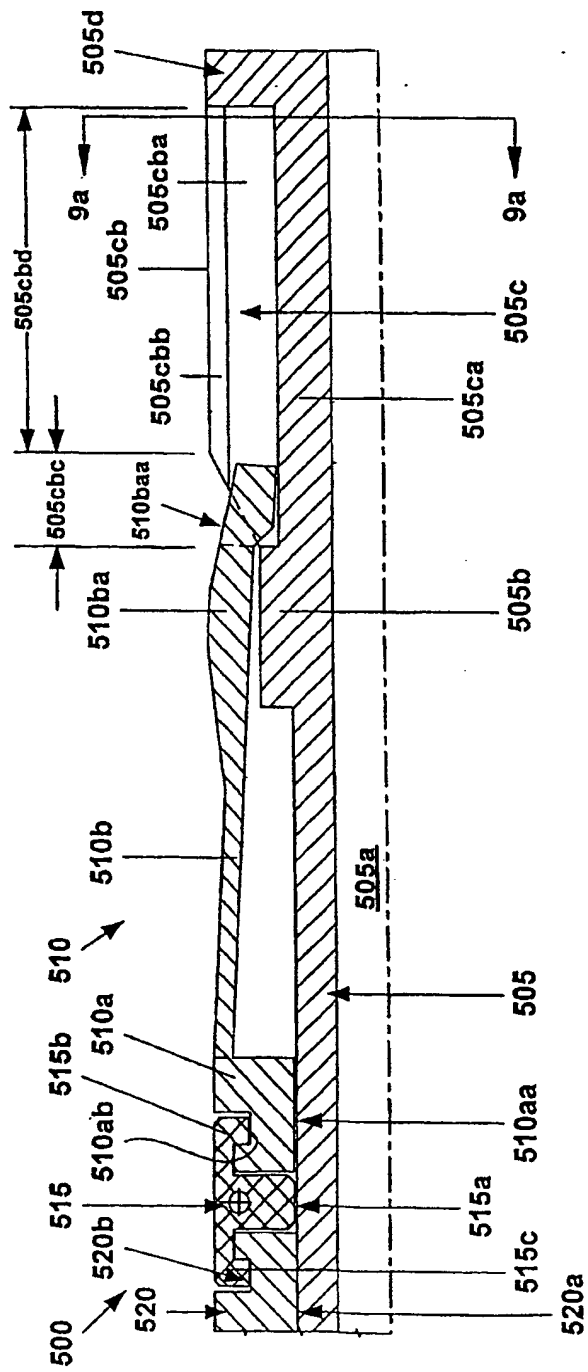


Fig. 9

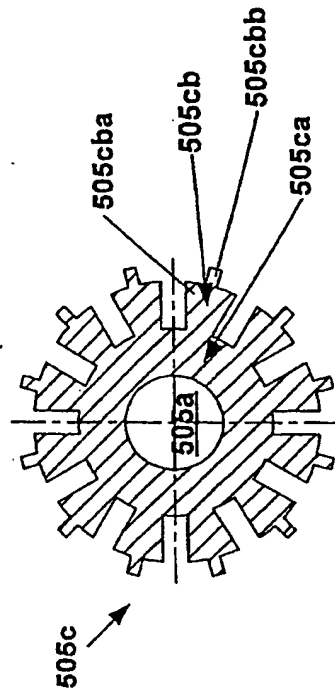


Fig. 9a

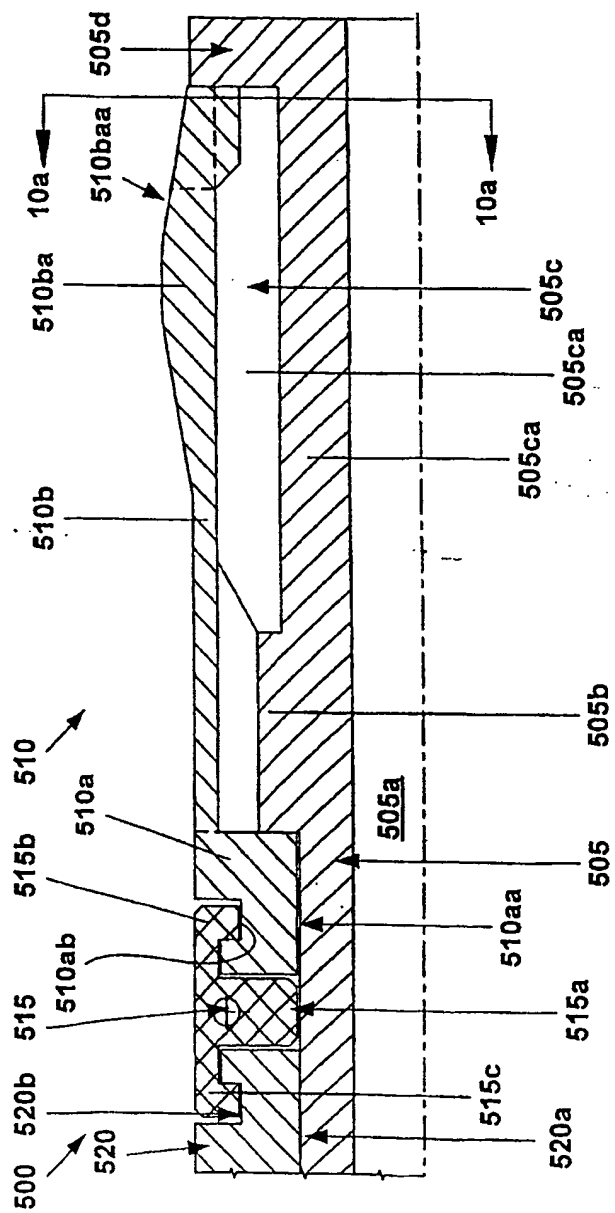


Fig. 10

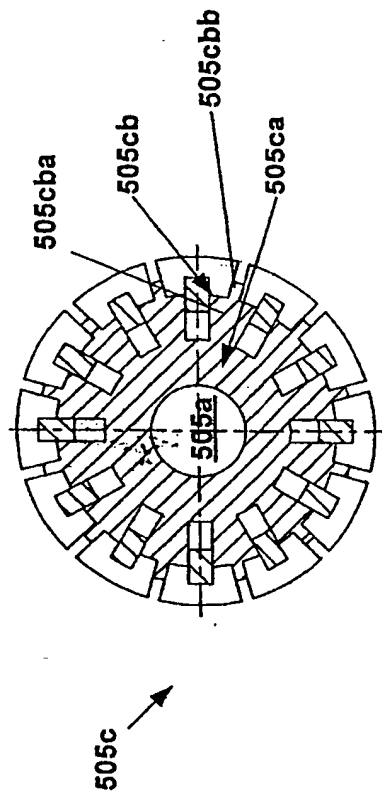


Fig. 10a

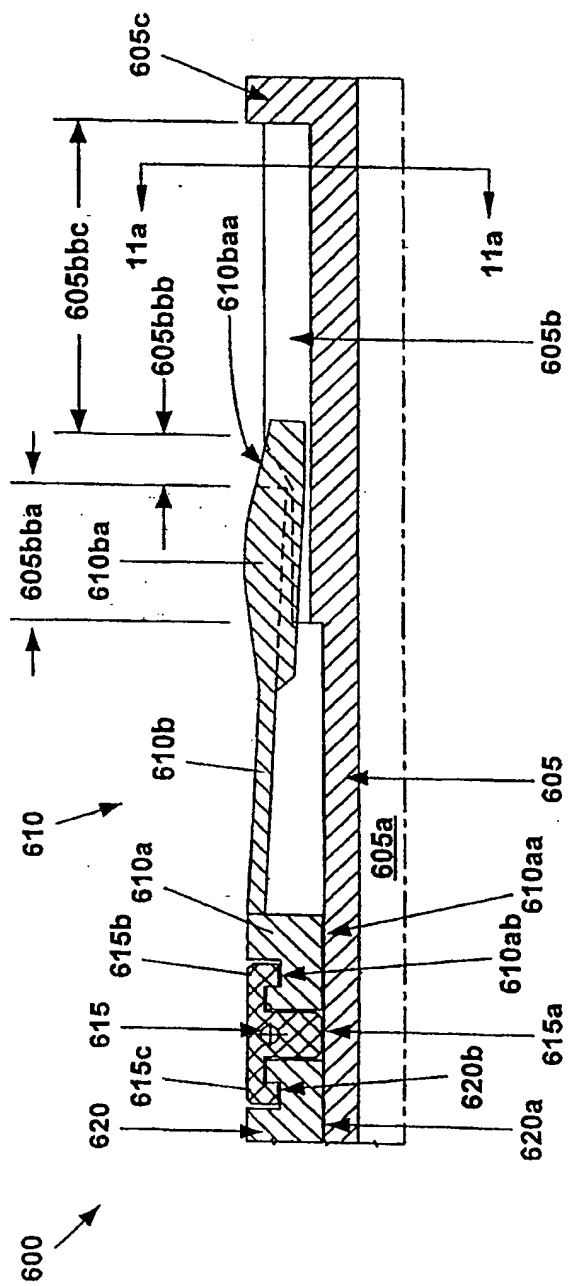


Fig. 11

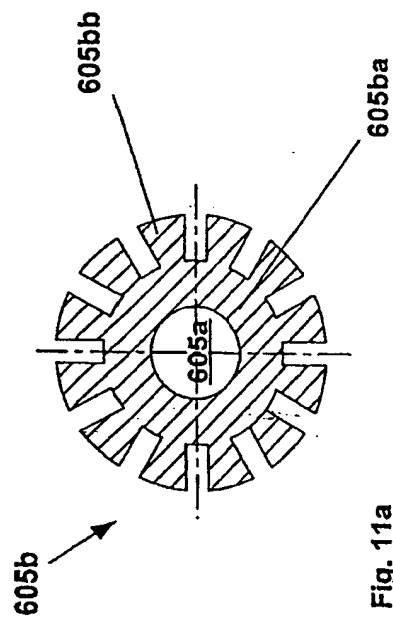


Fig. 11a

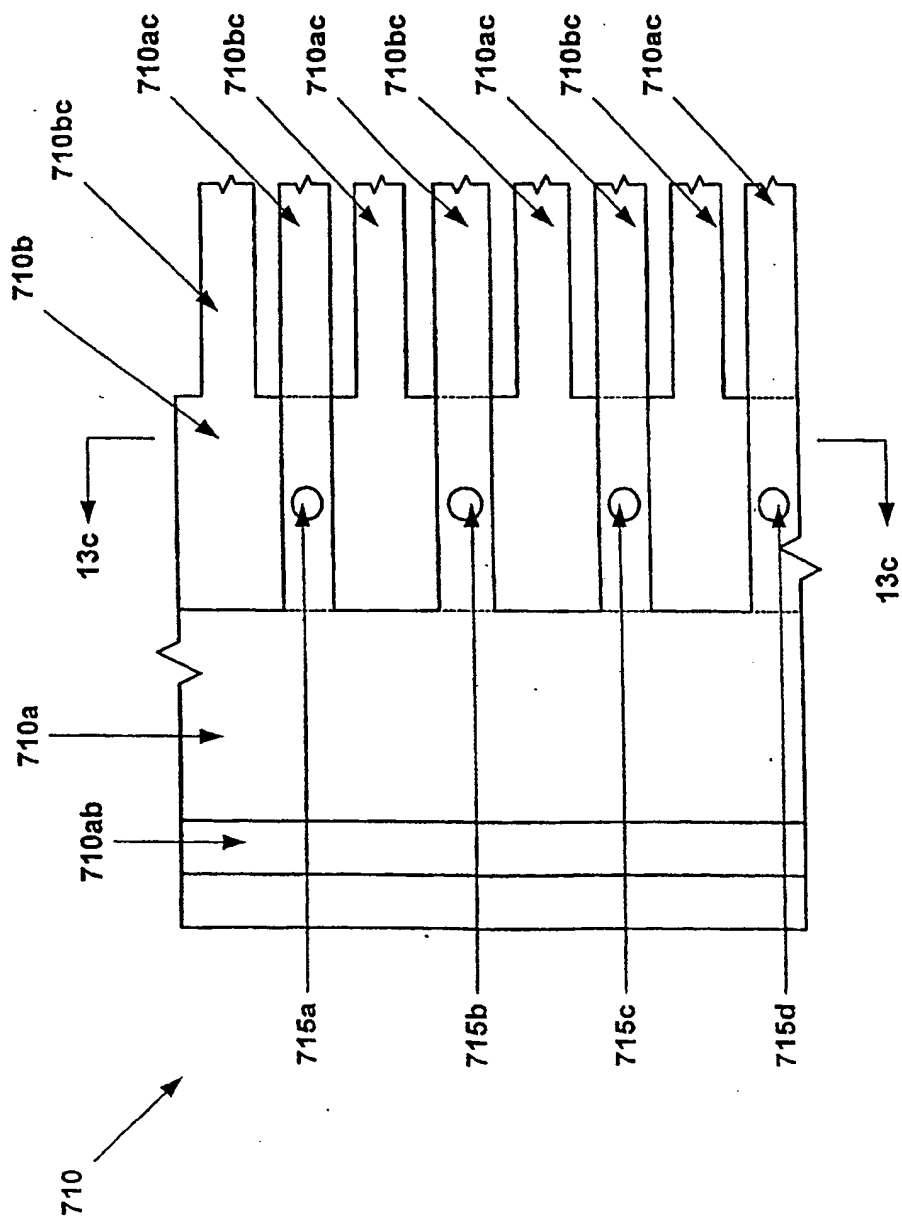


Fig. 13b

710 ↗

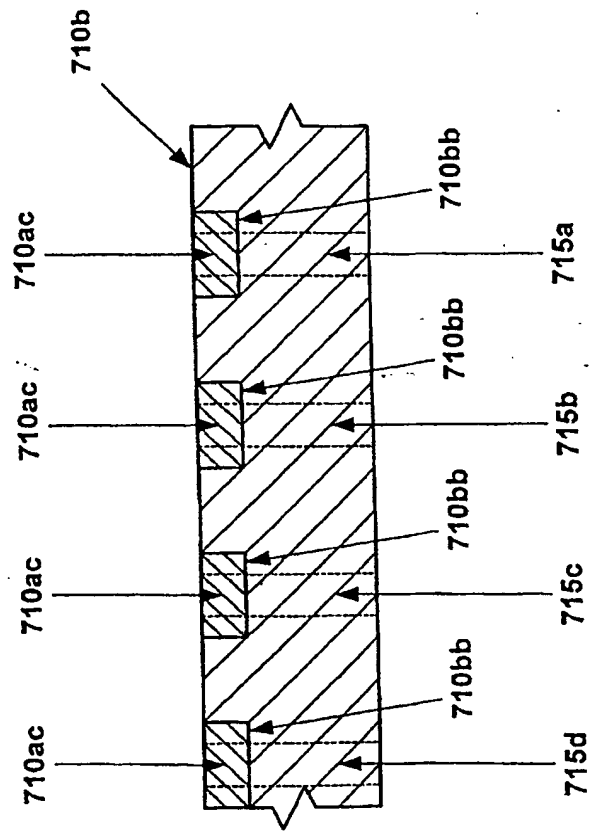


Fig. 13c

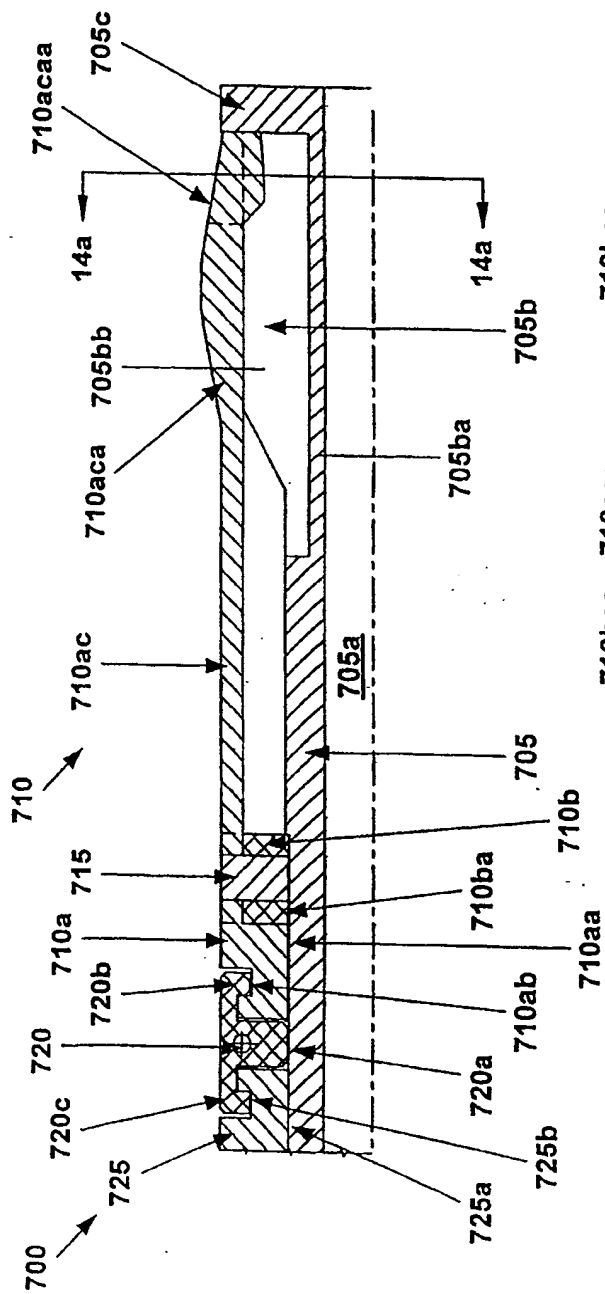


Fig. 14

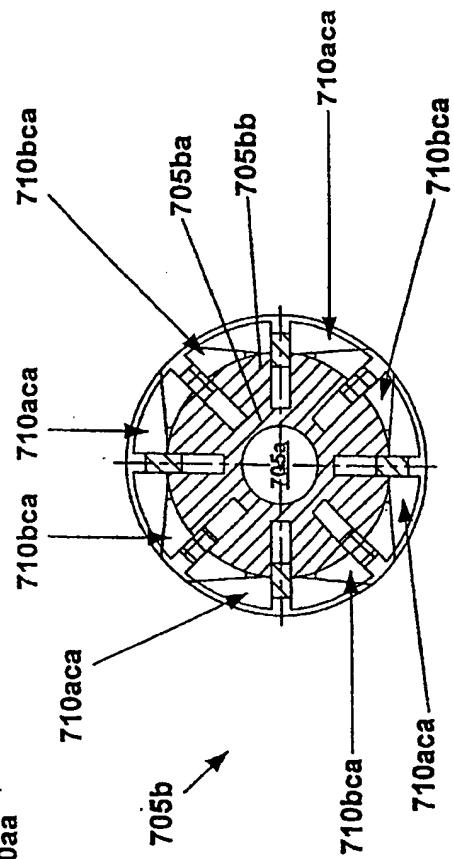


Fig. 14a

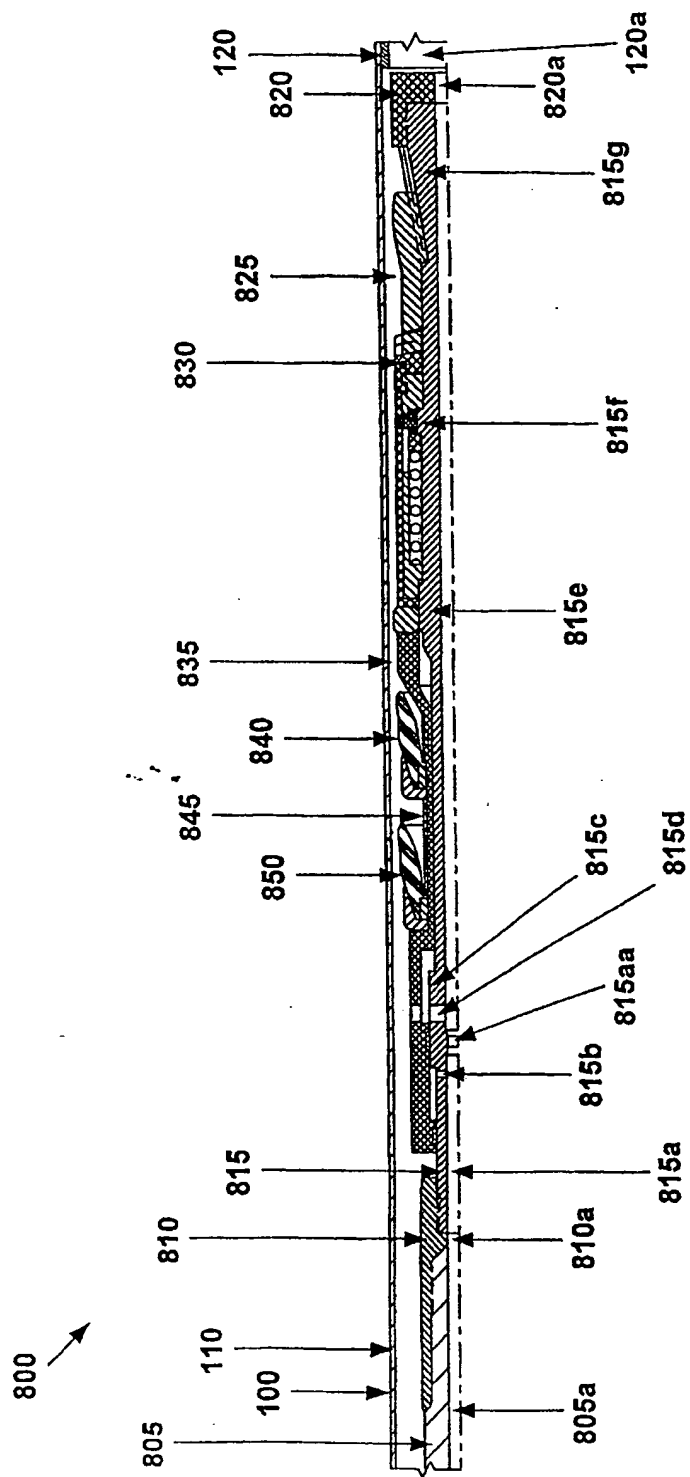


Fig. 15

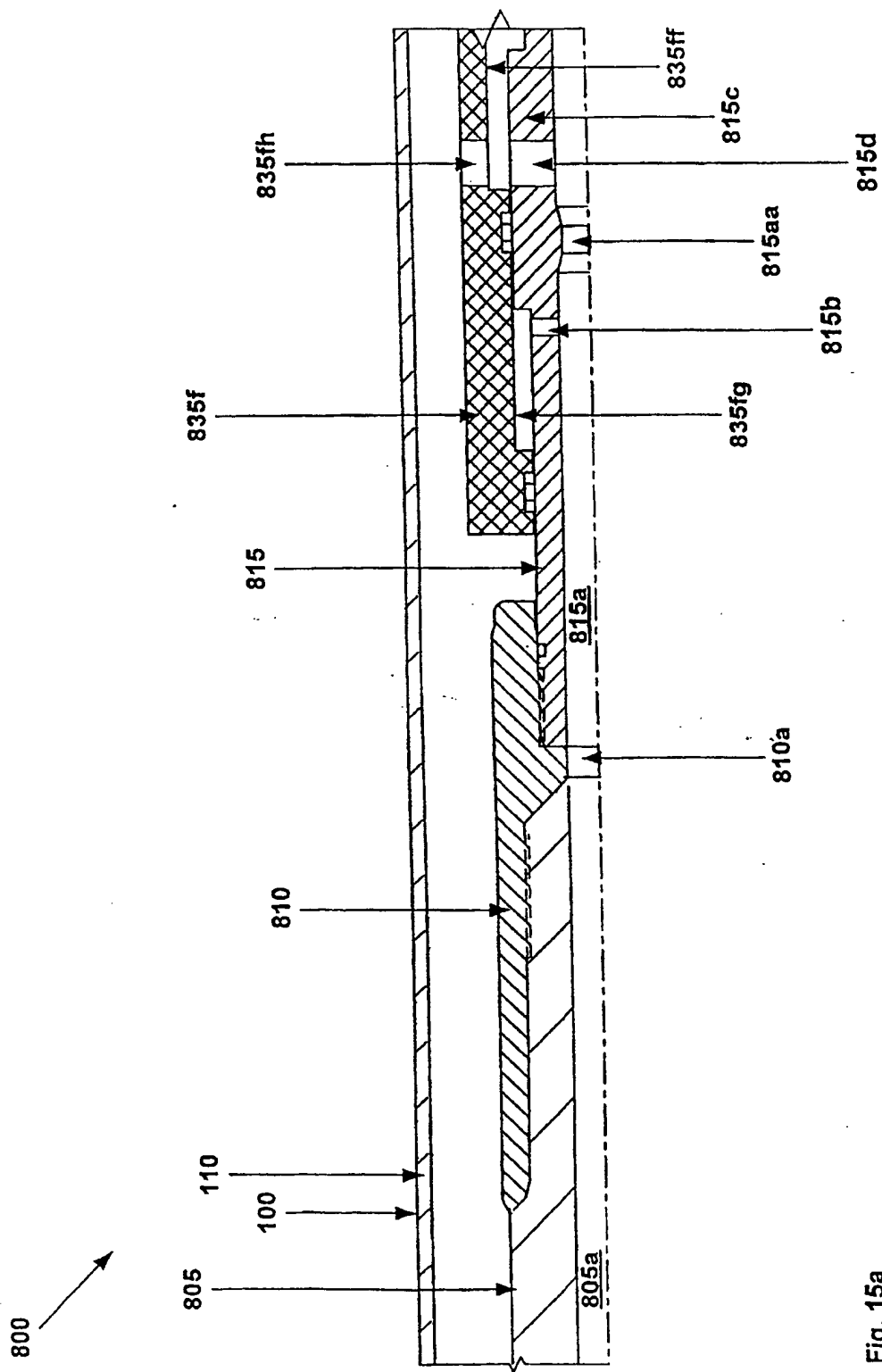


Fig. 15a

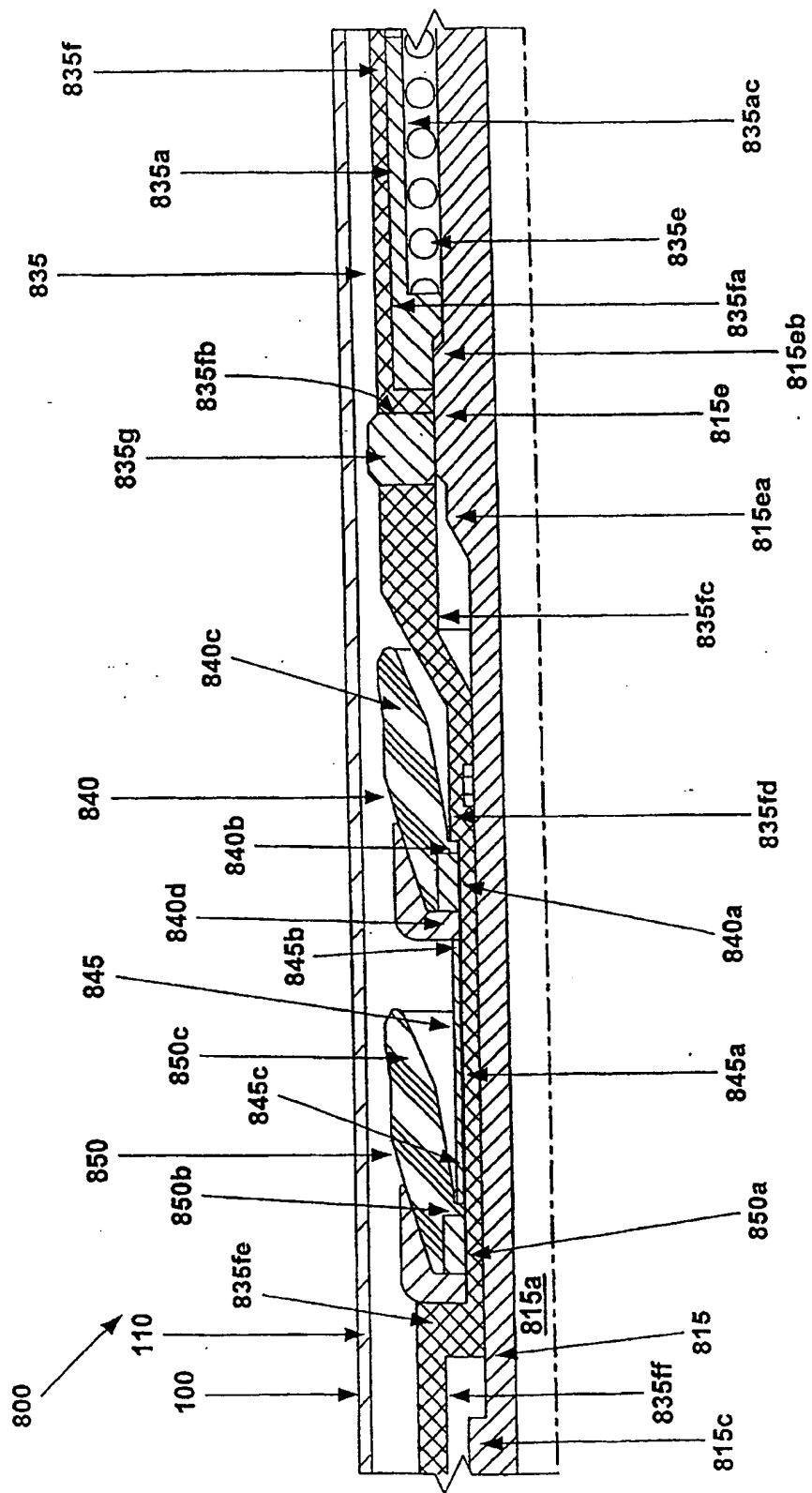


Fig. 15b

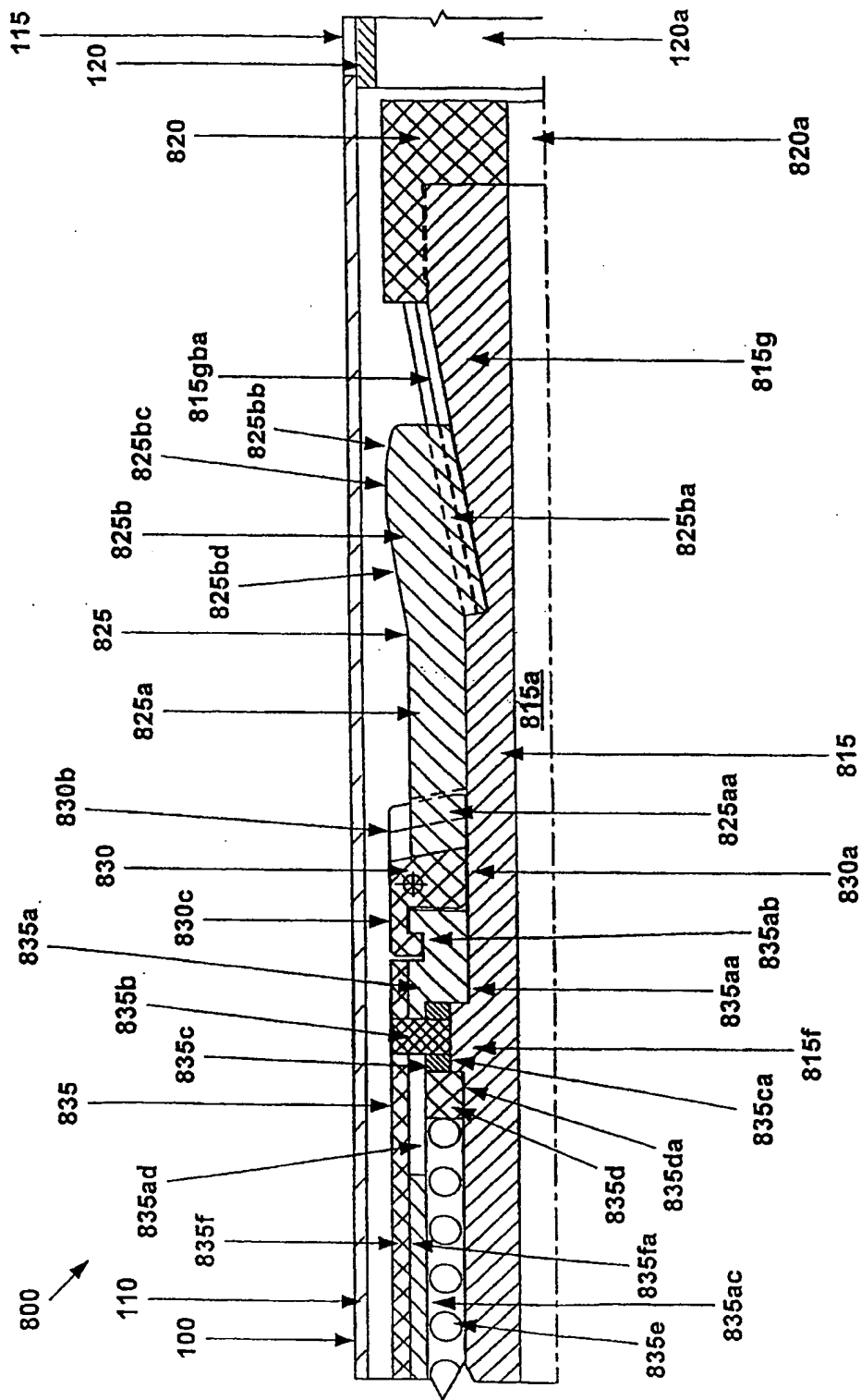


Fig. 15c

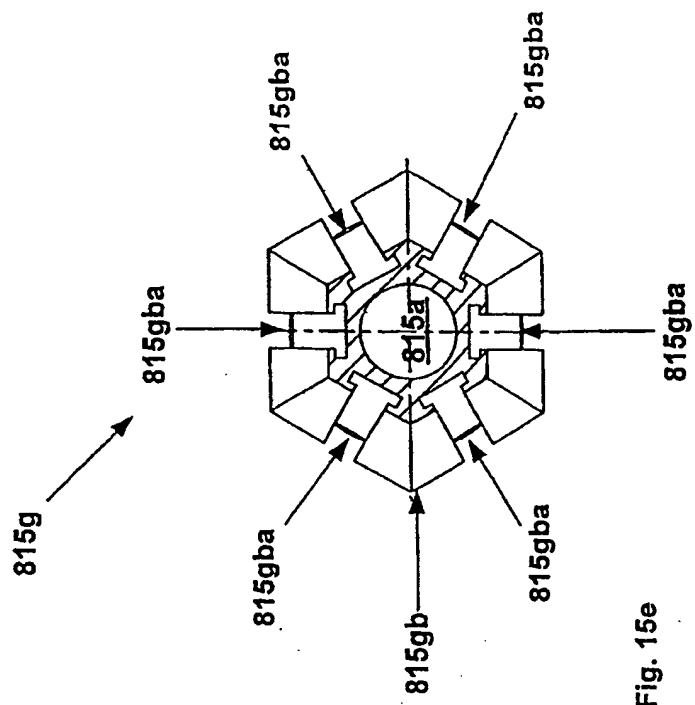


Fig. 15e

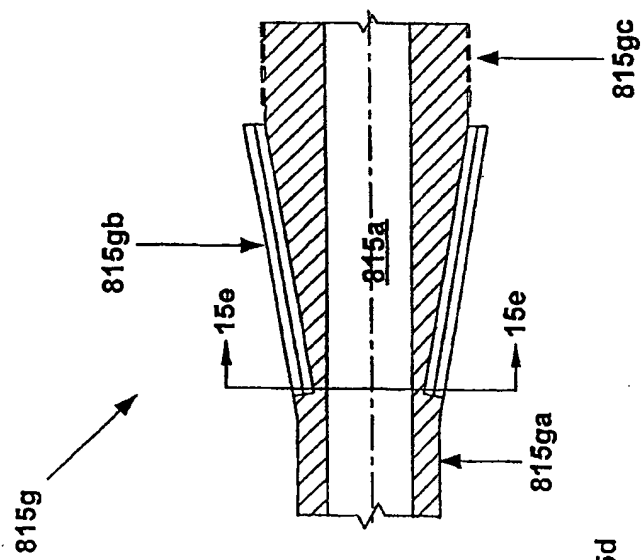


Fig. 15d

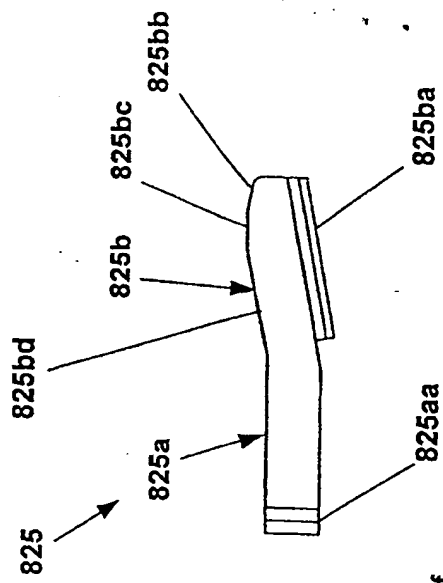


Fig. 15f

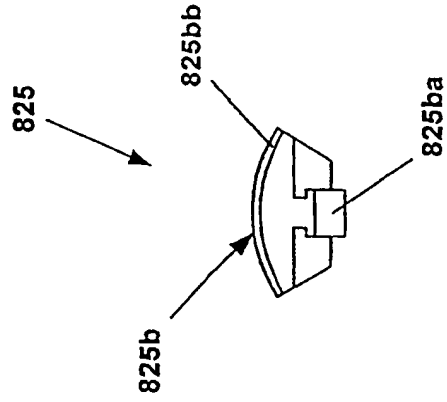


Fig. 15g

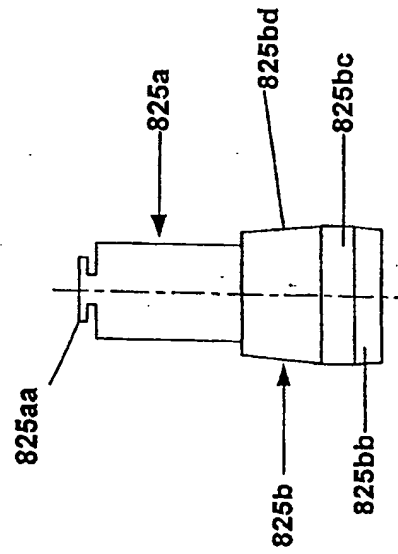


Fig. 15h

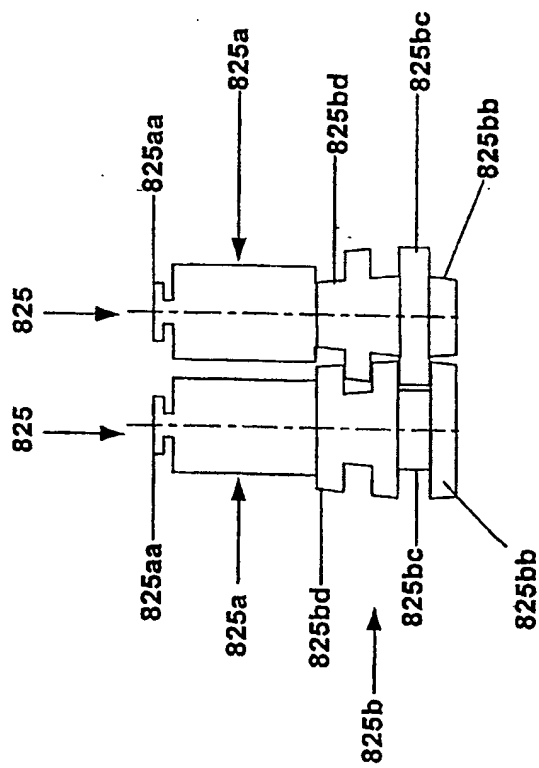


Fig. 15i

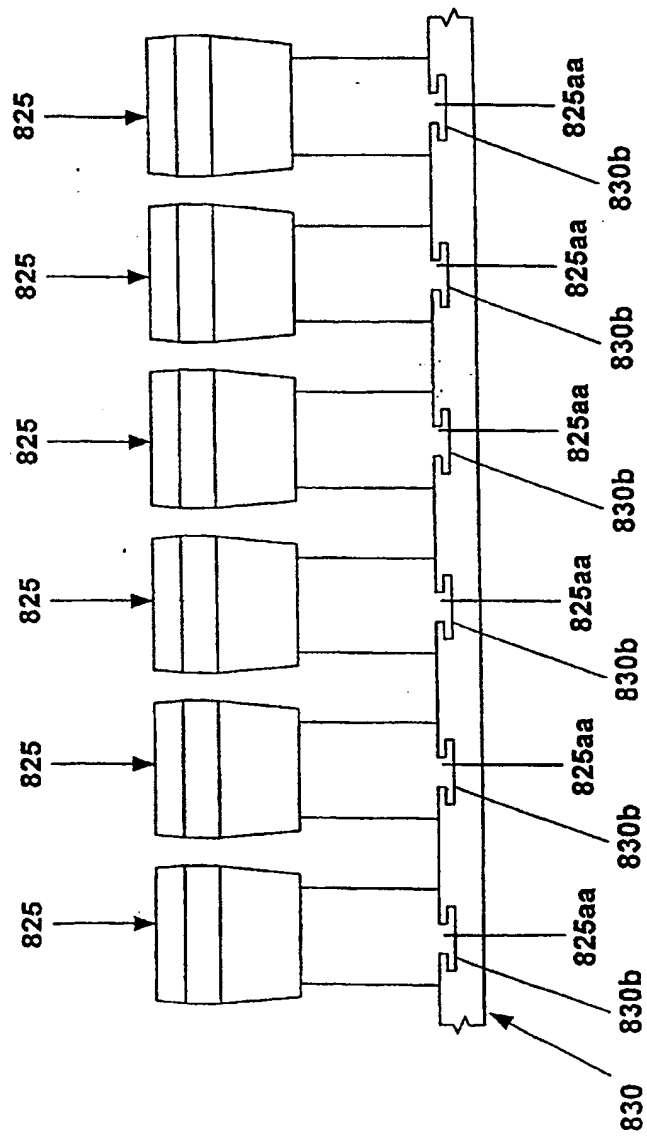


Fig. 15j

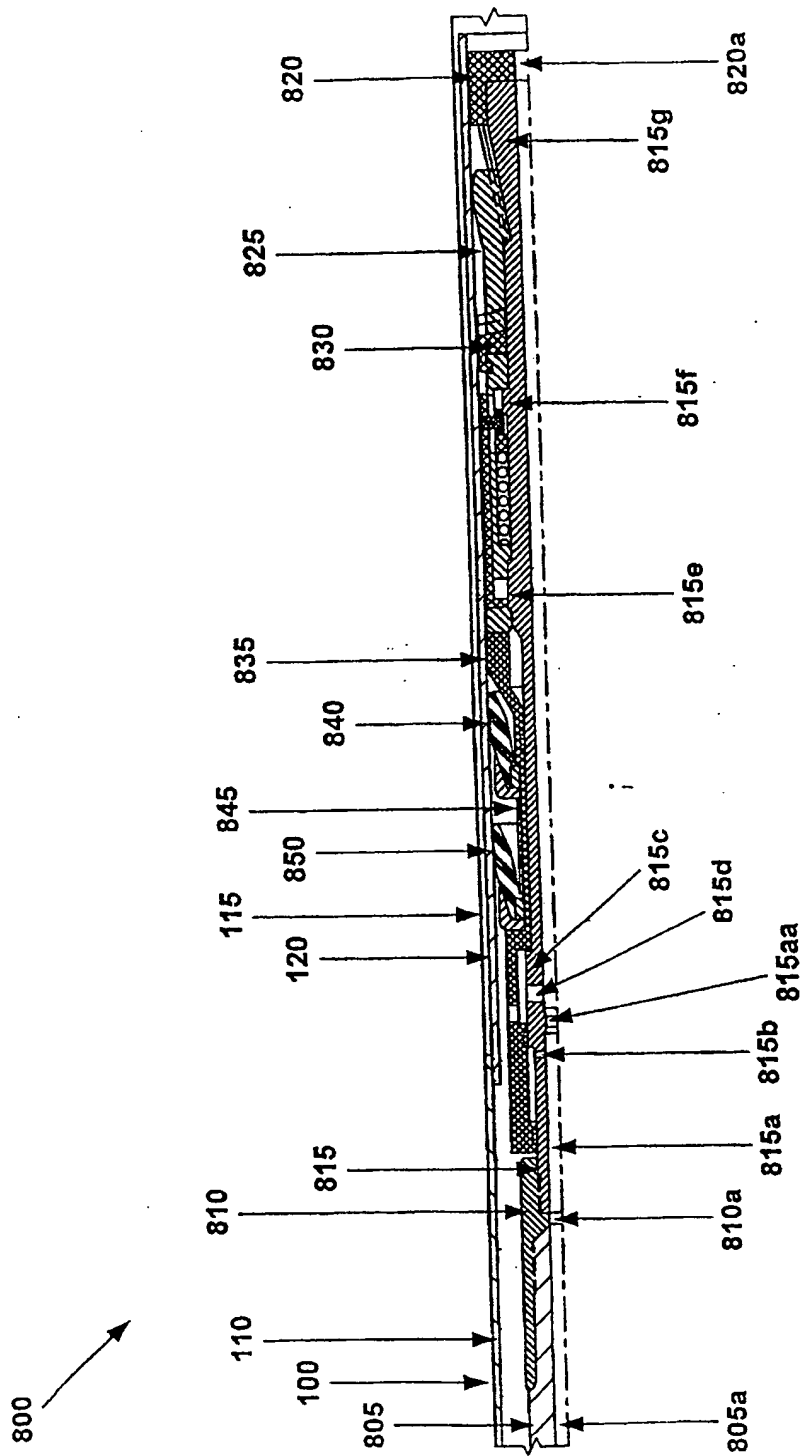


Fig. 16

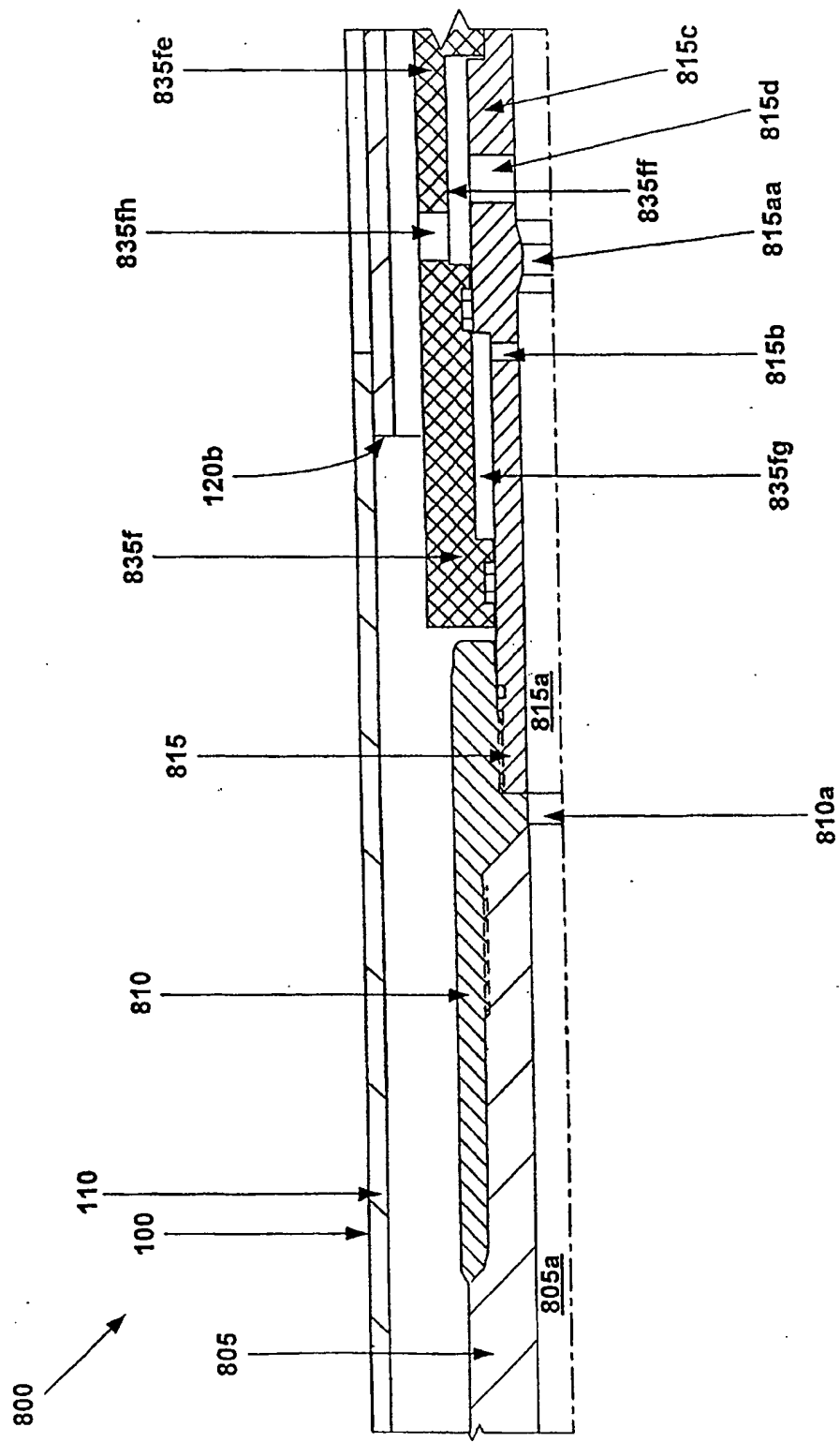


Fig. 16a

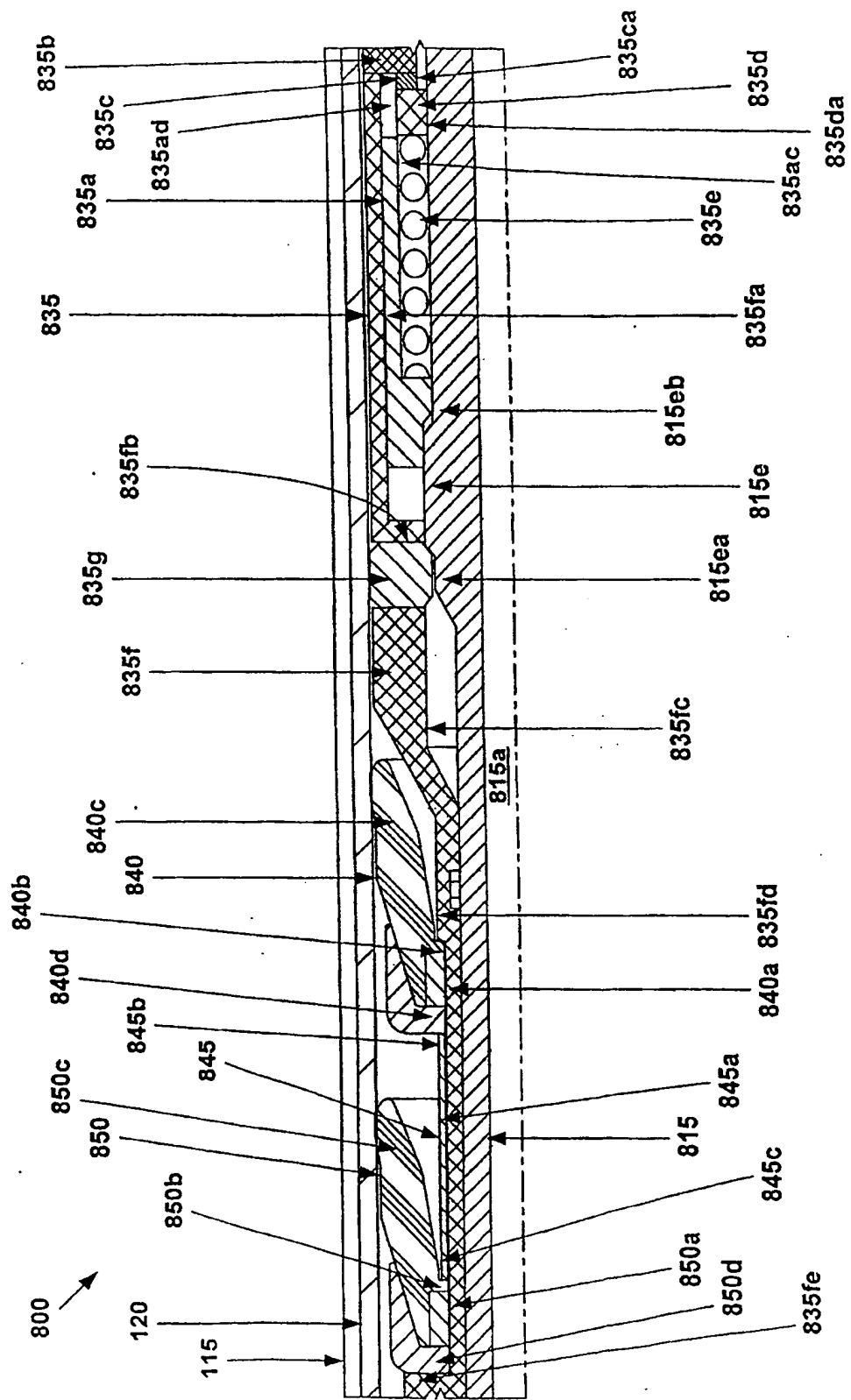


Fig. 16b

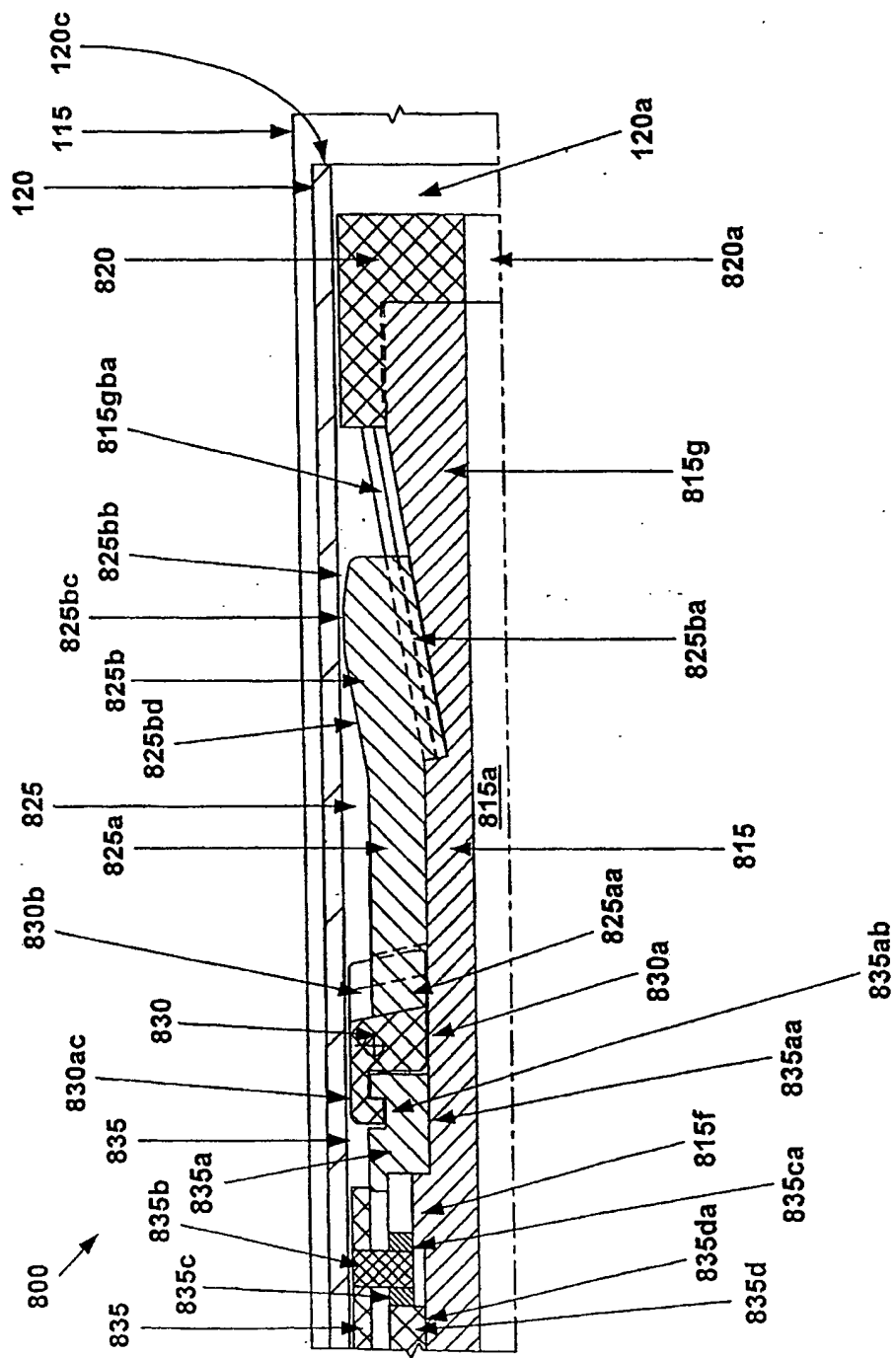


Fig. 16c

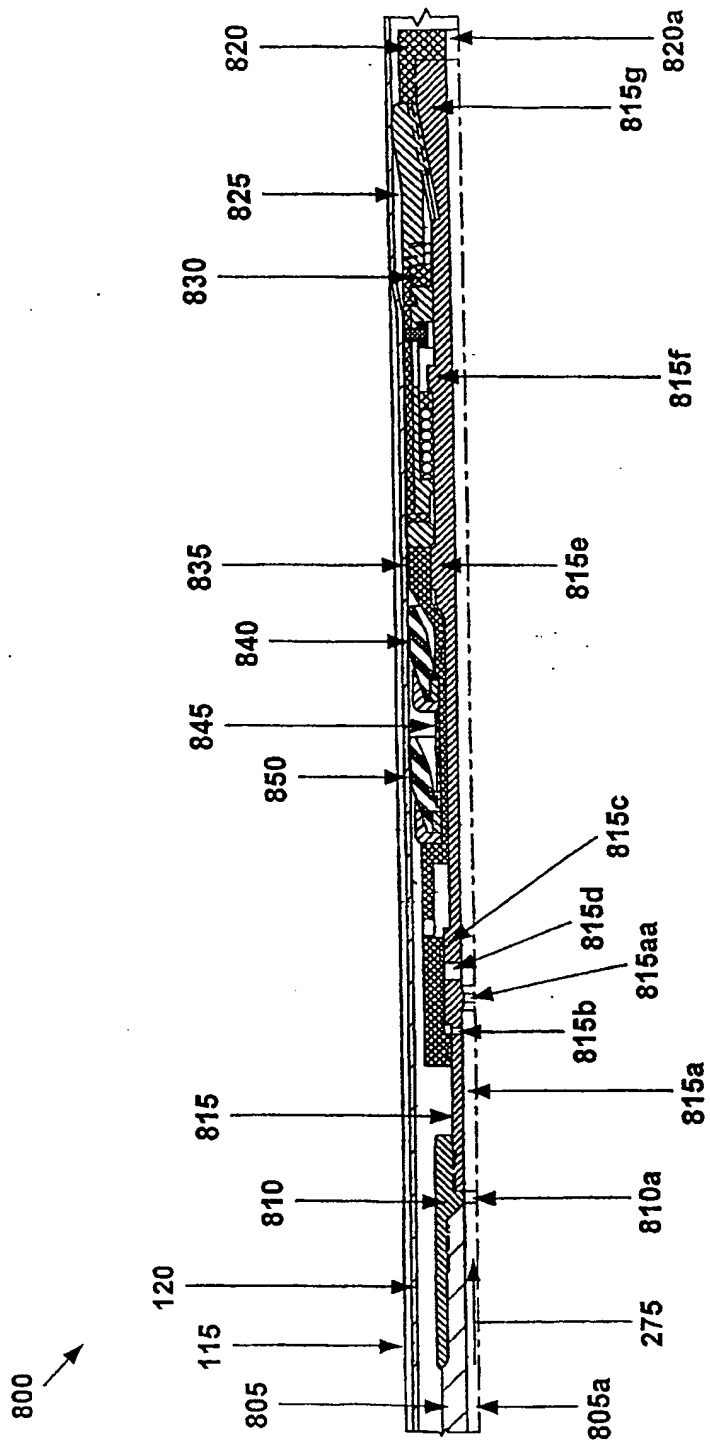


Fig. 17

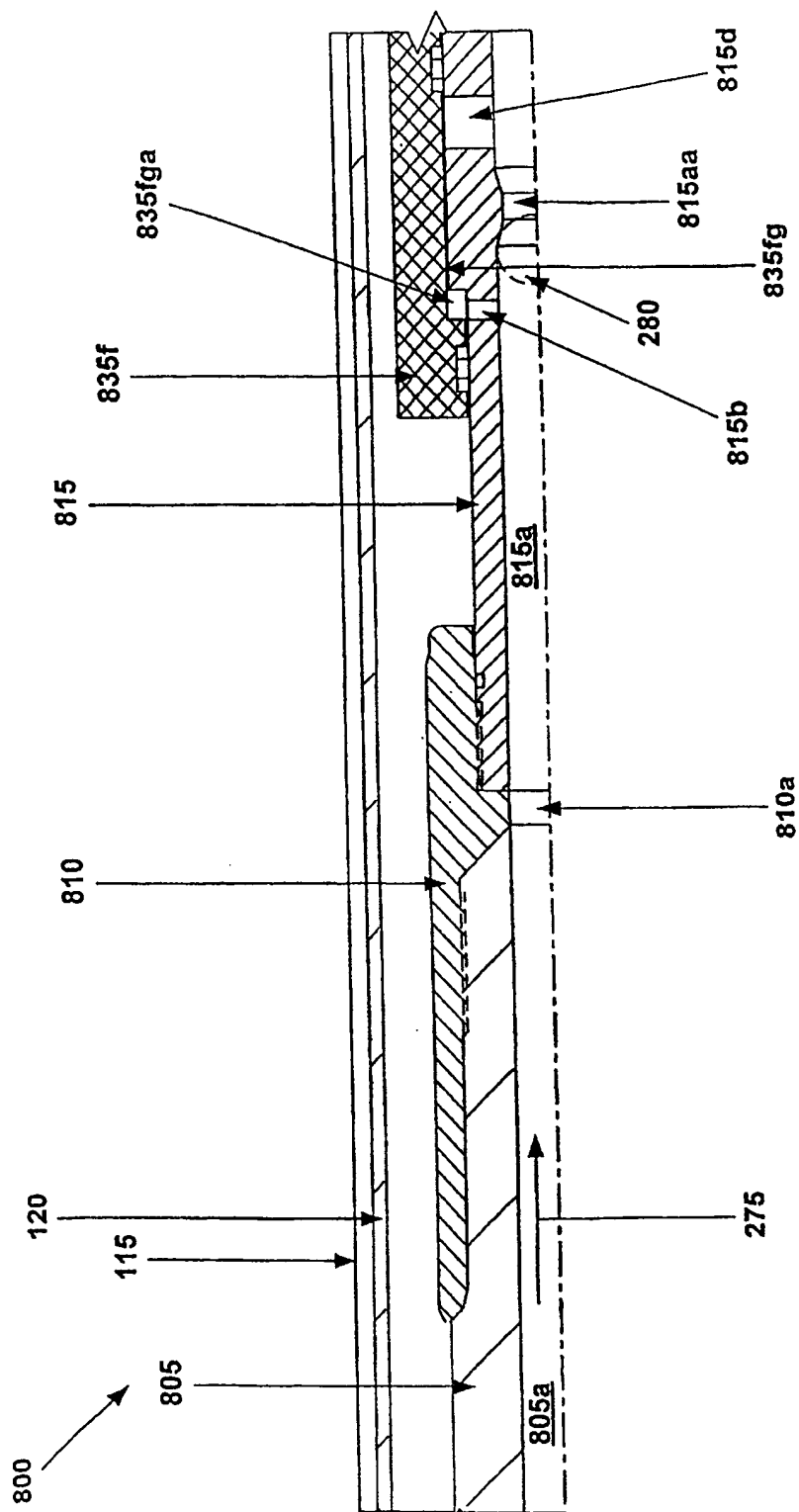


Fig. 17a

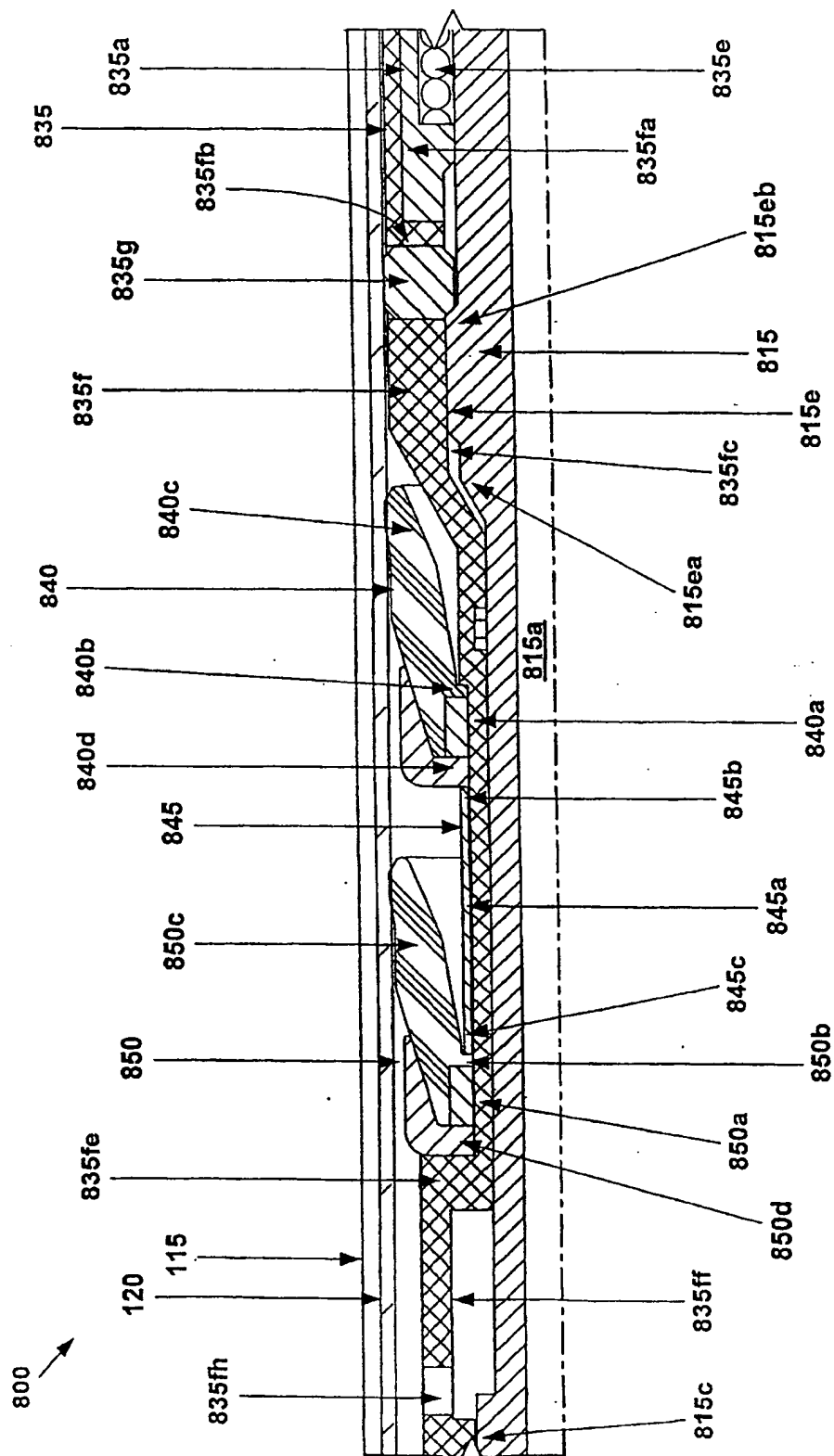
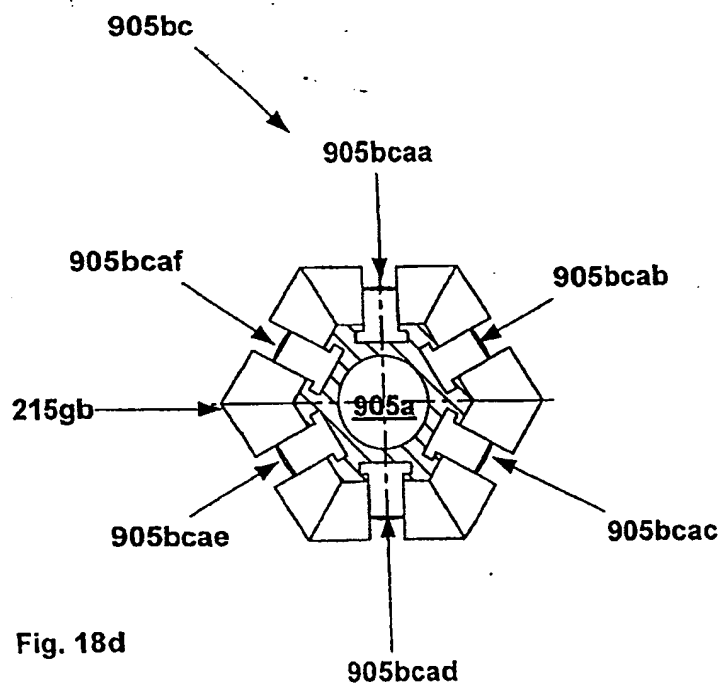
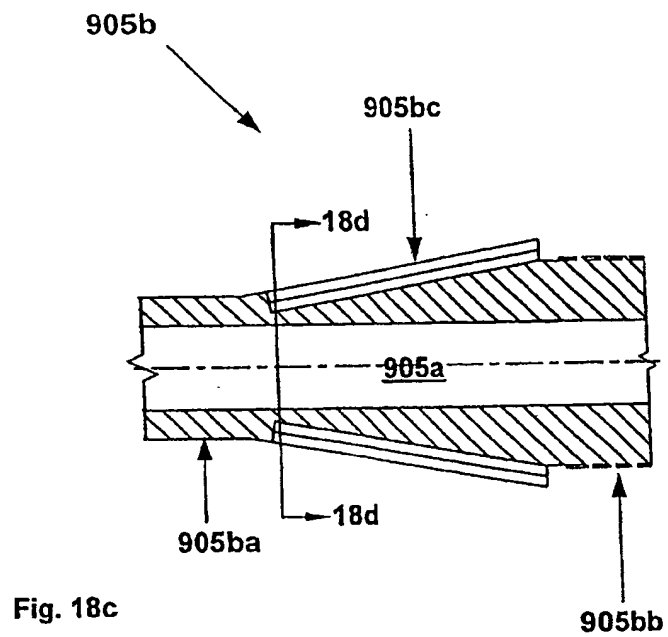


Fig. 17b



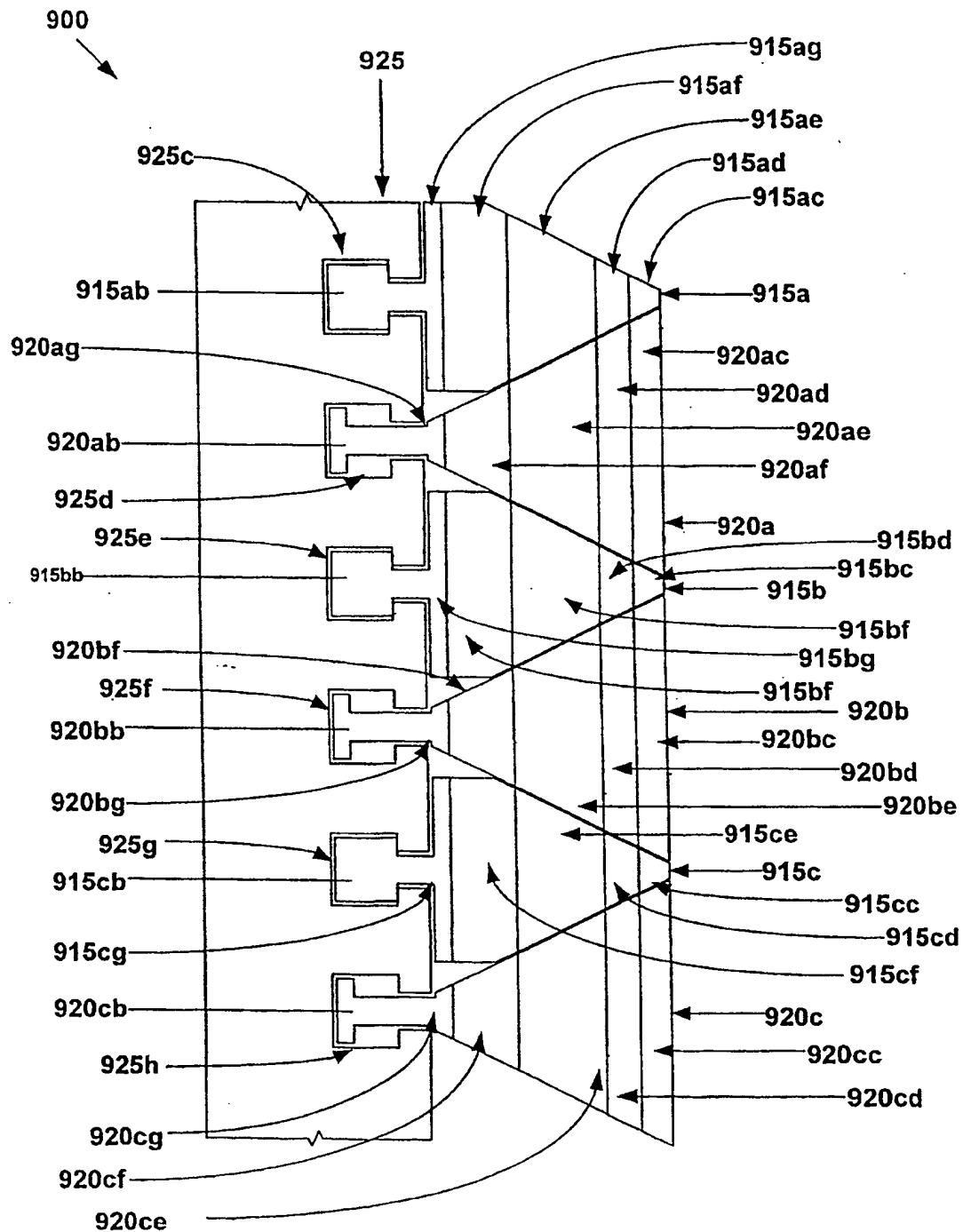


Fig. 19b

1000

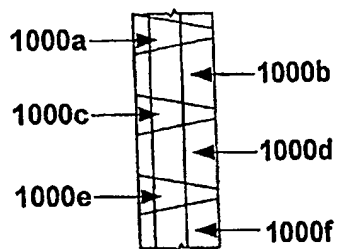


Fig. 20a

1100

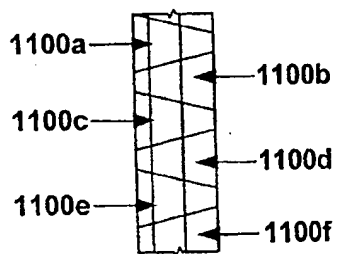


Fig. 20b

1200

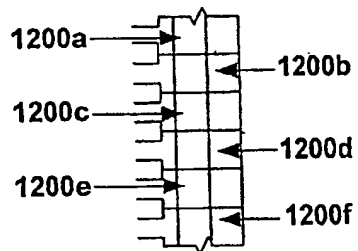


Fig. 20c

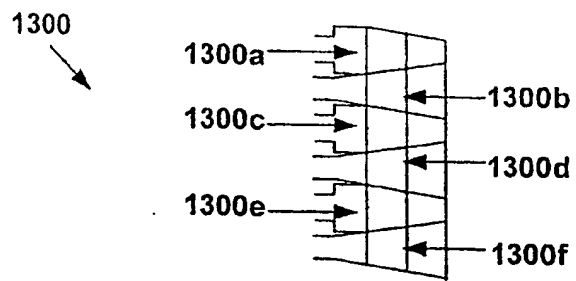


Fig. 20d

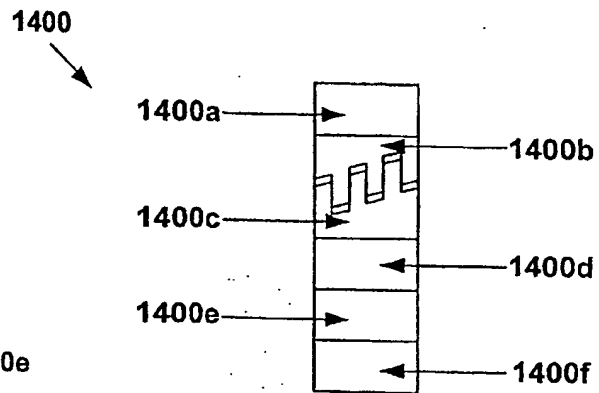


Fig. 20e

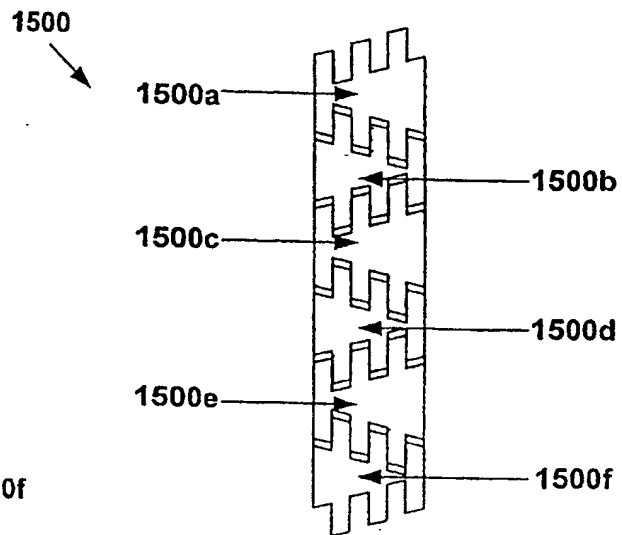


Fig. 20f

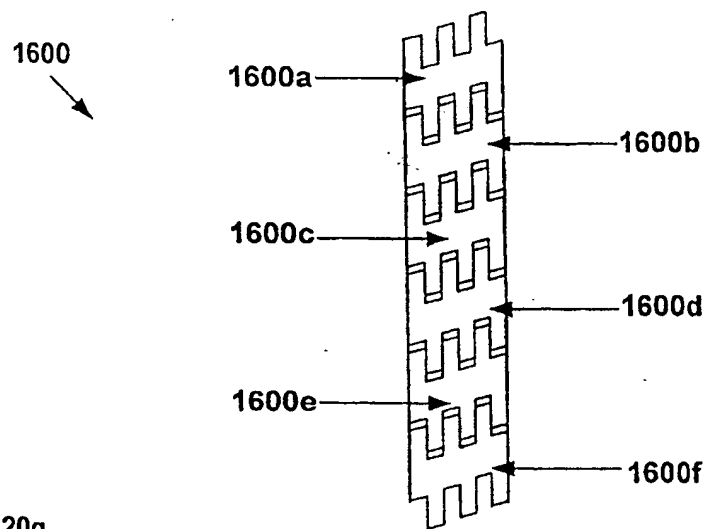


Fig. 20g

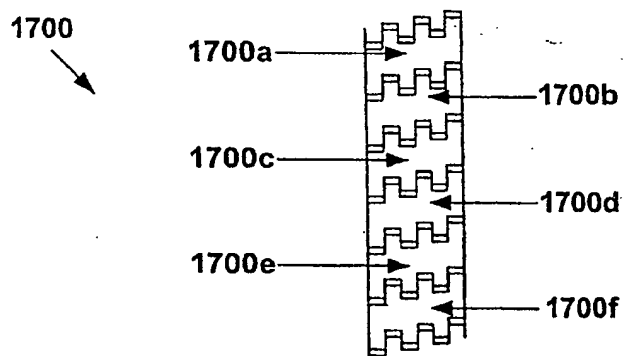


Fig. 20h

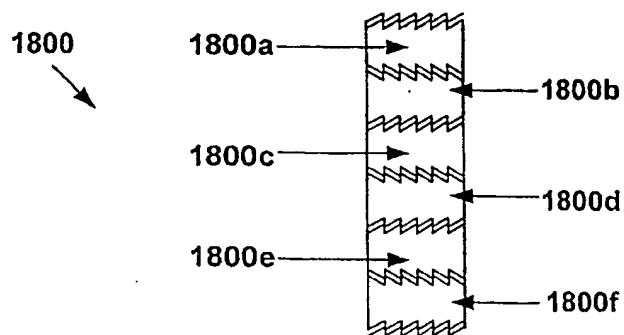


Fig. 20i

1900

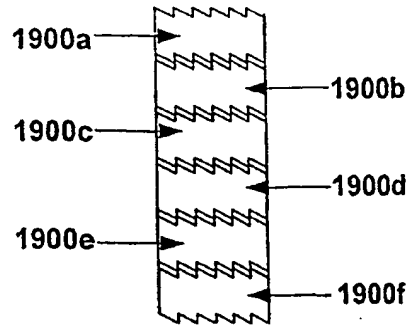


Fig. 20j

2000

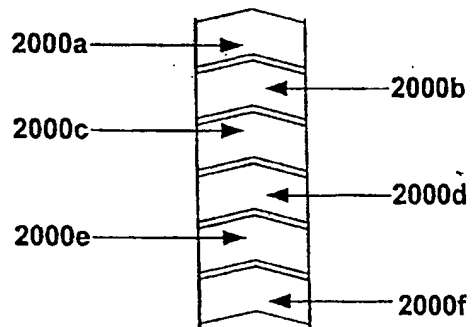


Fig. 20k

2100

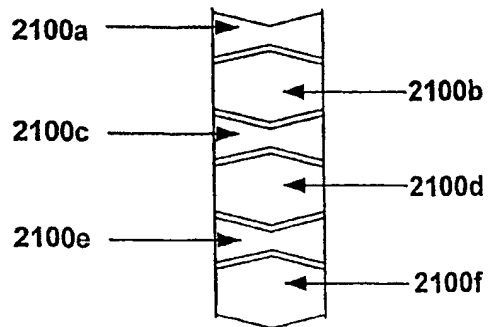


Fig. 20l

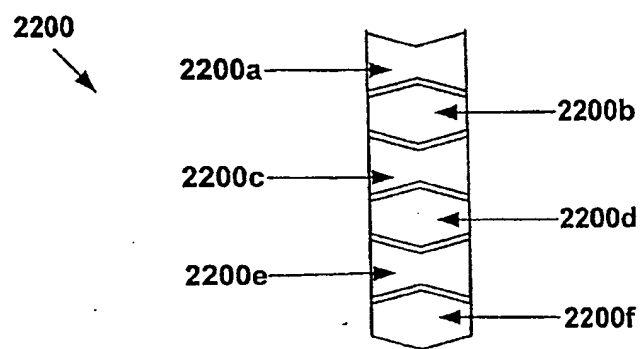


Fig. 20m

ADJUSTABLE EXPANSION CONE ASSEMBLY**Cross Reference To Related Applications**

This application claims the benefit of the filing date of U.S. provisional patent application serial no. 60/318,021, attorney docket no. 25791.58, filed on 9/7/2001, the disclosure of which is incorporated herein by reference.

This application is related to the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001; and (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001 the disclosures of which are incorporated herein by reference.

Background of the Invention

This invention relates generally to wellbore casings, and in particular to wellbore casings that are formed using expandable tubing.

Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings. Moreover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

The present invention is directed to overcoming one or more of the limitations of the existing procedures for forming new sections of casing in a wellbore.

Summary of the Invention

According to one aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first lug coupled to and extending from the first tubular support body in the radial direction, a second lug coupled to and extending from the first tubular support body in the radial direction, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body and a

second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar assembly is movably coupled to the exterior of the tubular support member that includes a second tubular support body defining N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first drag block assembly is movably coupled to the tubular support member that includes a first drag block body defining a slot for receiving and mating with the L-shaped retaining member of the split ring collar, and a first J-shaped slot for receiving the first lug, and one or more first drag blocks coupled to the first drag block body. A second drag block assembly is movably coupled to the tubular support member that includes a second drag block body defining a second J-shaped slot for receiving the second lug, and one or more second drag blocks coupled to the second drag block body. First and second packer cups are coupled to the tubular support member between the first and second drag block assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, a second tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A first collet assembly is movably coupled to the tubular support member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a first radial

passage, a first spring received within the first counterbore, a first retaining ring
 received within the first counterbore, a first load transfer pin coupled to the first
 retaining ring and extending through the first radial passage, a second tubular sleeve
 coupled to the first load transfer pin, a first resilient collet coupled to the second tubular
 sleeve and positioned above the first tapered flange, and a third tubular sleeve coupled
 5 to the first resilient collet. A second collet assembly is movably coupled to the tubular
 support member that includes a fourth tubular sleeve that defines a second
 counterbore for receiving the second flange, and a second radial passage, a second
 spring received within the second counterbore, a second retaining ring received within
 10 the second counterbore, a second load transfer pin coupled to the second retaining
 ring and extending through the second radial passage, a fifth tubular sleeve coupled to
 the second load transfer pin, a second resilient collet coupled to the fifth tubular sleeve
 and positioned above the second tapered flange, and a sixth tubular sleeve coupled to
 the second resilient collet. First and second packer cups coupled to the tubular support
 15 member between the first and second collet assemblies.

According to another aspect of the present invention, an apparatus for radially
 expanding a tubular member is provided that includes a tubular support member that
 includes a first tubular support body defining a longitudinal passage, a first radial
 passage defined in the first tubular support body fluidically coupled to the longitudinal
 20 passage, a first flange coupled to the first tubular support body, a second flange
 coupled to the first tubular support body, a first tapered flange coupled to the first
 tubular support body, a second tapered flange coupled to the first tubular support body,
 and an expansion cone support body coupled to the first tubular support body. The
 expansion cone support body includes an N-sided tapered tubular support member,
 25 wherein each side of the multi-sided tapered tubular support member defines a T-
 shaped slot. N expansion cone segments are movably coupled to the expansion cone
 support body, each including an expansion cone segment body including arcuate
 conical outer surfaces, a first T-shaped retaining member coupled to the expansion
 cone segment body for movably coupling the expansion cone segment body to a
 30 corresponding one of the T-shaped slots of the expansion cone support body, and a
 second T-shaped retaining member coupled to the expansion cone segment body. A
 split ring collar is movably coupled to the exterior of the tubular support member that
 includes a second tubular support body that defines N T-shaped slots for movably
 receiving corresponding ones of the second T-shaped retaining members of the
 35 expansion cone segments, and an L-shaped retaining member coupled to the second
 tubular support body. A first dog assembly is movably coupled to the tubular support

member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a second radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the second radial passage, and a second tubular sleeve coupled to the first load transfer pin that defines a second counterbore for receiving the first tubular sleeve, a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange. A second dog assembly is movably coupled to the tubular support member that includes a third tubular sleeve that defines a second counterbore for receiving the second flange, a third radial passage, and a fourth radial passage fluidically coupled to the first radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the third radial passage, a fourth tubular sleeve coupled to the second load transfer pin, and a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange. First and second packer cups are coupled to the tubular support member between the first and second dog assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage including a throat passage, a first radial passage defined in the first tubular support body fluidically coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body that defines a second radial passage defined in the second flange fluidically coupled to the longitudinal passage, a tapered flange coupled to the first tubular support body, and an expansion cone support body coupled to the first tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular

support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar, a first counterbore for receiving the first flange, and a third radial passage, a spring received within the first counterbore, a retaining ring received within the first counterbore, a load transfer pin coupled to the retaining ring and extending through the third radial passage, a second tubular sleeve coupled to the first load transfer pin that defines a first counterbore for receiving the first tubular sleeve, a second counterbore for receiving and mating with the tapered flange, and includes a third flange that defines a third counterbore for receiving the second flange, a fourth counterbore for receiving the second flange, and a fourth radial passage, and a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange. First and second packer cups are coupled to the tubular support member between the resilient dog and the third flange.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a tubular support body and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. N expansion cone segments are movably coupled to the expansion cone support body, each including an expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the expansion cone segment body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second T-shaped retaining members of the expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N stepped slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, and N expansion cone segments extending from the second tubular support member. Each expansion cone segment includes a resilient collet coupled to the second tubular support member, an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the stepped slots of the expansion cone support body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with the L-shaped slot of the second tubular support body of the expansion cone assembly, and a second L-shaped retaining member coupled to the third tubular body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, and N expansion cone segments extending from the second tubular support member. Each expansion cone segment includes a resilient collet coupled to the second tubular support member, an expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with

the L-shaped slot of the second tubular support body, and a second L-shaped retaining member coupled to the third tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the tubular support body. The expansion cone support body includes a tapered tubular support member defining N slots. An expansion cone assembly is movably coupled to the tubular support member that includes a second tubular support body movably coupled to the first tubular support body defining an L-shaped slot, N/2 first expansion cone segments extending from the second tubular support member, and N/2 second expansion cone segments extending from the second tubular member. Each first expansion cone segment includes a first resilient collet coupled to the second tubular support member, a first expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a first retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. Each second expansion cone segment includes a second resilient collet coupled to the second tubular support member, a second expansion cone segment body coupled to the resilient collet including arcuate conical outer surfaces, and a second retaining member coupled to the expansion cone segment body for movably coupling the expansion cone segment body to a corresponding one of the slots of the expansion cone support body. The second expansion cone segments overlap and are interleaved with the first expansion cone segments. A split ring collar is movably coupled to the exterior of the tubular support member that includes a third tubular support body, a first L-shaped retaining member coupled to the third tubular support body for mating with L-shaped slot of the second tubular support body, and a second L-shaped retaining member coupled to the third tubular support body. A tubular actuating sleeve is movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the second L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member that includes a first tubular support body, and an expansion cone support body coupled to the first tubular

support body. The expansion cone support body includes an N-sided tapered tubular support member, wherein each side of the multi-sided tapered tubular support member defines a T-shaped slot. $N/2$ first expansion cone segments are movably coupled to the expansion cone support body, each including a first expansion cone segment body including arcuate conical outer surfaces, a first T-shaped retaining member coupled to the first expansion cone segment body for movably coupling the first expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a second T-shaped retaining member coupled to the first expansion cone segment body. $N/2$ second expansion cone segments are also movably coupled to the expansion cone support body, each including a second expansion cone segment body including arcuate conical outer surfaces, a third T-shaped retaining member coupled to the second expansion cone segment body for movably coupling the second expansion cone segment body to a corresponding one of the T-shaped slots of the expansion cone support body, and a fourth T-shaped retaining member coupled to the expansion cone segment body. The first and second expansion cone segments are interleaved. The first expansion cone segment bodies are complementary shaped with respect to the second expansion cone segment bodies. A split ring collar assembly is movably coupled to the exterior of the tubular support member that includes a second tubular support body that defines N T-shaped slots for movably receiving corresponding ones of the second and fourth T-shaped retaining members of the interleaved first and second expansion cone segments, and an L-shaped retaining member coupled to the second tubular support body. A tubular actuating sleeve movably coupled to the tubular support member that includes a third tubular support body that defines a slot for receiving and mating with the L-shaped retaining member of the split ring collar.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first lug coupled to and extending from the first tubular support body in the radial direction, and a second lug coupled to and extending from the first tubular support body in the radial direction. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first drag block assembly is movably coupled to the tubular support member that includes a first drag block body coupled to the adjustable expansion cone assembly that defines: a first J-shaped slot for receiving the first lug, and one or more first drag blocks coupled to the first drag block body. A second drag block assembly is

movably coupled to the tubular support member that includes a second drag block body that defines: a second J-shaped slot for receiving the second lug, and one or more second drag blocks coupled to the second drag block body. First and second packer cups are coupled to the tubular support member between the first and second drag block assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first tubular support body, and a second tapered flange coupled to the first tubular support body. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first collet assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly and defines a first counterbore for receiving the first flange, and a first radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the first radial passage, a second tubular sleeve coupled to the first load transfer pin, a first resilient collet coupled to the second tubular sleeve and positioned above the first tapered flange, and a third tubular sleeve coupled to the first resilient collet. A second collet assembly is movably coupled to the tubular support member that includes a fourth tubular sleeve that defines: a second counterbore for receiving the second flange, and a second radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the second radial passage, a fifth tubular sleeve coupled to the second load transfer pin, a second resilient collet coupled to the fifth tubular sleeve and positioned above the second tapered flange, and a sixth tubular sleeve coupled to the second resilient collet. First and second packer cups are coupled to the tubular support member between the first and second collet assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage, a first radial passage defined in the first tubular support body fluidically coupled to the longitudinal passage, a first flange coupled to the first tubular support body, a second flange coupled to the first tubular support body, a first tapered flange coupled to the first

tubular support body, and a second tapered flange coupled to the first tubular support body. An adjustable expansion cone assembly is movably coupled to the tubular support member. A first dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly that defines: a first counterbore for receiving the first flange, and a second radial passage, a first spring received within the first counterbore, a first retaining ring received within the first counterbore, a first load transfer pin coupled to the first retaining ring and extending through the second radial passage, a second tubular sleeve coupled to the first load transfer pin that defines: a second counterbore for receiving the first tubular sleeve, a first resilient dog coupled to the second tubular sleeve and positioned adjacent to the first tapered flange. A second dog assembly is movably coupled to the tubular support member that includes a third tubular sleeve that defines a second counterbore for receiving the second flange; a third radial passage, and a fourth radial passage fluidically coupled to the first radial passage, a second spring received within the second counterbore, a second retaining ring received within the second counterbore, a second load transfer pin coupled to the second retaining ring and extending through the third radial passage, a fourth tubular sleeve coupled to the second load transfer pin, a second resilient dog coupled to the fourth tubular sleeve and positioned adjacent to the second tapered flange. First and second packer cups are coupled to the tubular support member between the first and second dog assemblies.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member that includes a first tubular support body defining a longitudinal passage including a throat passage, a first radial passage defined in the first tubular support body fluidically coupled to the longitudinal passage, a first flange coupled to the first tubular support body, and a second flange coupled to the first tubular support body that defines: a second radial passage defined in the second flange fluidically coupled to the longitudinal passage. An adjustable expansion cone assembly is movably coupled to the tubular support member. A dog assembly is movably coupled to the tubular support member that includes a first tubular sleeve coupled to the adjustable expansion cone assembly that defines a first counterbore for receiving the first flange, and a third radial passage, a spring received within the first counterbore, a retaining ring received within the first counterbore, a load transfer pin coupled to the retaining ring and extending through the third radial passage, a second tubular sleeve coupled to the first load transfer pin that defines: a first counterbore for receiving the first tubular sleeve.

for receiving and mating with the tapered flange, and includes a third flange that defines a third counterbore for receiving the second flange, a fourth counterbore for receiving the second flange, and a fourth radial passage, and a resilient dog coupled to the second tubular sleeve and positioned adjacent to the tapered flange. First and
5 second packer cups are coupled to the tubular support member between the resilient dog and the third flange.

According to another aspect of the present invention, an apparatus for radially expanding a tubular member is provided that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member,
10 and means for adjusting the adjustable expansion cone assembly.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a tubular support member. An adjustable expansion cone is movably coupled to the tubular support member that includes a plurality of expansion cone segments, and means for guiding the expansion cone
15 segments on the tubular support member. The assembly further includes means for adjusting the adjustable expansion cone.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes guiding the expansion cone segments on a tapered body, and
20 controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes guiding the expansion cone segments on a multi-sided tapered body, interlocking the expansion cone segments, and controllably displacing
25 the expansion cone segments along the tapered body.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes resiliently guiding the expansion cone segments on a multi-sided tapered body, guiding each of the expansion cone segments on opposite sides in
30 the circumferential direction, interlocking the expansion cone segments, and controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes dividing the expansion cone segments into first and second
35 groups of expansion cone segments, interleaving the first and second groups of

segments, resiliently guiding the expansion cone segments on a multi-sided tapered body, guiding each of the expansion cone segments on opposite sides in the circumferential direction, and controllably displacing the expansion cone segments along the tapered body.

5 According to another aspect of the present invention, a method of operating an adjustable expansion cone assembly including a plurality of expansion cone segments is provided that includes dividing the expansion cone segments into first and second groups of expansion cone segments, interleaving the first and second groups of expansion cone segments, guiding the expansion cone segments on a multi-sided
10 tapered body, and controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

 According to another aspect of the present invention, a method of plastically deforming and radially expanding an expandable tubular member using an apparatus
15 including a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, is provided that includes coupling a first end of the expandable tubular member to a tubular structure, locking the actuator to the tubular support member of the apparatus, inserting the
20 apparatus into the first end of the expandable tubular member, moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member, reinserting the actuator of the apparatus into the second end of the expandable tubular member, unlocking the actuator from the tubular support member of the apparatus, rotating the actuator relative to the tubular support member
25 of the apparatus, and increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly and the expandable tubular member, and plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member.

30 According to another aspect of the present invention, a method of plastically deforming and radially expanding an expandable tubular member using an apparatus including a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, and an actuator movably coupled to the tubular support member for adjusting the adjustable expansion cone assembly, is provided that
35 includes coupling a first end of the expandable tubular member to a tubular structure, inserting the apparatus into the first end of the expandable tubular member in a first

direction, displacing the actuator of the apparatus in a second direction opposite to the first direction, applying a resilient biasing force to the adjustable expansion cone assembly in the second direction, moving the actuator and the adjustable expansion cone assembly of the apparatus out of the second end of the expandable tubular member, reinserting the actuator of the apparatus into the second end of the expandable tubular member in the second direction, increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in the first direction, and plastically deforming and radially expanding the expandable tubular member by moving the adjustable expansion cone assembly through the expandable tubular member in the second direction.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for guiding the expansion cone segments on a tapered body, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for guiding the expansion cone segments on a multi-sided tapered body, means for interlocking the expansion cone segments, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for resiliently guiding the expansion cone segments on a multi-sided tapered body, means for guiding each of the expansion cone segments on opposite sides in the circumferential direction, means for interlocking the expansion cone segments, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for dividing the expansion cone segments into first and second groups of expansion cone segments, means for interleaving the first and second groups of expansion cone segments, means for overlapping the first and second groups of expansion cone segments, means for resiliently guiding the expansion cone segments on a multi-sided tapered body, means for guiding each of the expansion cone segments on opposite sides in the circumferential direction, and means for controllably displacing the expansion cone segments along the tapered body.

According to another aspect of the present invention, an adjustable expansion cone assembly is provided that includes a plurality of expansion cone segments, means for dividing the expansion cone segments into first and second groups of expansion cone segments, means for interleaving the first and second groups of expansion cone segments, means for guiding the expansion cone segments on a multi-
 5 expansion cone segments, means for guiding the expansion cone segments on a multi-sided tapered body, and means for controllably displacing the expansion cone segments along the tapered body while also relatively displacing the first and second groups of expansion cone segments in opposite directions.

According to another aspect of the present invention, an apparatus for
 10 plastically deforming and radially expanding an expandable tubular member is provided that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, means for actuating the adjustable expansion cone assembly, means for locking the actuator to the tubular support member of the apparatus, means for unlocking the actuator from the tubular support
 15 member of the apparatus, and means for increasing the outside diameter of the adjustable expansion cone assembly by moving the tubular support member relative to the actuator, the adjustable expansion cone assembly, and the expandable tubular member.

According to another aspect of the present invention, an apparatus for
 20 plastically deforming and radially expanding an expandable tubular member is provided that includes a tubular support member, an adjustable expansion cone assembly movably coupled to the tubular support member, means for actuating the adjustable expansion cone assembly, means for displacing the actuator of the apparatus in a first direction, means for applying a resilient biasing force to the adjustable expansion cone
 25 assembly when the actuator is displaced in the first direction, and means for increasing the outside diameter of the adjustable expansion cone assembly by displacing the actuator and the adjustable expansion cone assembly relative to the expandable tubular member in a second direction opposite to the first direction.

Brief Description of the Drawings

30 Figs. 1 and 1a-1d are fragmentary cross-sectional views of an embodiment of the placement of an apparatus for radially expanding a tubular member within a tubular member within a borehole within a subterranean formation.

Fig. 1e is a cross-sectional view of an embodiment of the expansion cone support body of the apparatus of Figs. 1 and 1a-1d.

35 Fig. 1f is a cross-sectional view of the expansion cone support body of Fig. 1e.

Fig. 1g is a side view of an embodiment of an expansion cone segment for use in the apparatus of Figs. 1 and 1a-1d.

Fig. 1h is a front view of the expansion cone segment of Fig. 1g.

Fig. 1i is a top view of the expansion cone segment of Fig. 1g.

5 Fig. 1j is a top view of an embodiment of interlocking expansion cone segments for use in the apparatus of Figs. 1 and 1a-1d.

Fig. 1k is a top fragmentary circumferential view of an embodiment of the coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 1 and 1a-1d.

10 Figs. 1l and 1m are top schematic views of an embodiment of the coupling between the J-slots of the drag blocks and the lugs of the tubular support member of the apparatus of Figs. 1 and 1a-1d.

Figs. 2 and 2a-2d are fragmentary cross-sectional illustrations of the apparatus of Figs. 1 and 1a-1d during the radial expansion of the tubular member within the
15 borehole within the subterranean formation.

Figs. 2e and 2f are illustrations of an embodiment of the J-slots of the drag blocks and the lugs of the tubular support member of the apparatus of Figs. 2 and 2a-2d.

Figs. 2g and 2h are illustrations of an alternative embodiment of the J-slots of
20 the drag blocks and the lugs of the tubular support member of the apparatus of Figs. 2 and 2a-2d.

Figs. 3 and 3a-3c are fragmentary cross-sectional illustrations of an embodiment of the placement of an apparatus for radially expanding a tubular member within a wellbore casing within a subterranean formation.

25 Fig. 3d is a cross-sectional view of an embodiment of the expansion cone support body of the apparatus of Figs. 3 and 3a-3c.

Fig. 3e is a cross-sectional view of the expansion cone support body of Fig. 3d.

Fig. 3f is a side view of an embodiment of an expansion cone segment for use in the apparatus of Figs. 3 and 3a-3c.

30 Fig. 3g is a front view of the expansion cone segment of Fig. 3f.

Fig. 3h is a top view of the expansion cone segment of Fig. 3f.

Fig. 3i is a top view of an embodiment of interlocking expansion cone segments for use in the apparatus of Figs. 3 and 3a-3c.

Fig. 3j is a top fragmentary circumferential view of an embodiment of the
35 coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 3 and 3a-3c.

Figs. 4 and 4a-4d are fragmentary cross-sectional illustrations of an embodiment of the placement of the apparatus of Figs. 3 and 3a-3c including an expandable tubular member within an expandable tubular member within a subterranean formation.

5 Figs. 5 and 5a-5d are fragmentary cross-sectional illustrations of an embodiment of the operation of the apparatus of Figs. 4 and 4a-4d during the radial expansion of the expandable tubular member within the borehole within the subterranean formation.

10 Figs. 6 and 6a-6d are fragmentary cross-sectional illustrations of an embodiment of the placement of an apparatus for radially expanding a tubular member within a borehole within a subterranean formation.

Fig. 6e is a cross-sectional view of an embodiment of the expansion cone support body of the apparatus of Figs. 6 and 6a-6d.

Fig. 6f is a cross-sectional view of the expansion cone support body of Fig. 6e.

15 Fig. 6g is a side view of an embodiment of an expansion cone segment for use in the apparatus of Figs. 6 and 6a-6d.

Fig. 6h is a front view of the expansion cone segment of Fig. 6g.

Fig. 6i is a top view of the expansion cone segment of Fig. 6g.

20 Fig. 6j is a top view of an embodiment of interlocking expansion cone segments for use in the apparatus of Figs. 6 and 6a-6d.

Fig. 6k is a top fragmentary circumferential view of an embodiment of the coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 6 and 6a-6d.

25 Figs. 7 and 7a-7c are fragmentary cross-sectional illustrations of an embodiment of the placement of the apparatus of Figs. 6 and 6a-6d including an expandable tubular member within a borehole within a subterranean formation.

30 Figs. 8 and 8a-8d are fragmentary cross-sectional illustrations of an embodiment of the operation of the apparatus of Figs. 7 and 7a-7d during the radial expansion of the expandable tubular member within a borehole within a subterranean formation.

Fig. 9 is a fragmentary cross sectional illustration of an embodiment of an expansion cone assembly in an unexpanded position.

Fig. 9a is a cross sectional illustration of the expansion cone assembly of Fig. 9.

35 Fig. 10 is a fragmentary cross sectional illustration of the expansion cone assembly of Fig. 9 in an expanded position.

Fig. 10a is a cross sectional illustration of the expansion cone assembly of Fig.
10.

Fig. 11 is a fragmentary cross sectional illustration of an embodiment of an
expansion cone assembly in an unexpanded position.

5 Fig. 11a is a cross sectional illustration of the expansion cone assembly of Fig.
11.

Fig. 12 is a fragmentary cross sectional illustration of the expansion cone
assembly of Fig. 11 in an expanded position.

Fig. 12a is a cross sectional illustration of the expansion cone assembly of Fig.
10 12.

Fig. 13 is a fragmentary cross sectional illustration of an embodiment of an
expansion cone assembly in an unexpanded position.

Fig. 13a is a cross sectional illustration of the expansion cone assembly of Fig.
13.

15 Fig. 13b is a fragmentary top circumferential illustration of the expansion cone
segment assembly of Fig. 13 that illustrates the interleaved sets of collets.

Fig. 13c is a fragmentary cross sectional illustration of the interleaved collets of
Fig. 13b.

Fig. 14 is a fragmentary cross sectional illustration of the expansion cone
20 assembly of Fig. 13 in an expanded position.

Fig. 14a is a cross sectional illustration of the expansion cone assembly of Fig.
14.

Figs. 15 and 15a-15c are fragmentary cross-sectional illustrations of an
embodiment of the placement of an apparatus for radially expanding a tubular member
25 within a borehole within a subterranean formation.

Fig. 15d is a cross-sectional view of an embodiment of the expansion cone
support body of the apparatus of Figs. 15 and 15a-15c.

Fig. 15e is a cross-sectional view of the expansion cone support body of Fig.
15d.

30 Fig. 15f is a side view of an embodiment of an expansion cone segment for use
in the apparatus of Figs. 15 and 15a-15c.

Fig. 15g is a front view of the expansion cone segment of Fig. 15f.

Fig. 15h is a top view of the expansion cone segment of Fig. 15f.

Fig. 15i is a top view of an embodiment of interlocking expansion cone
35 segments for use in the apparatus of Figs. 15 and 15a-15c.

Fig. 15j is a top fragmentary circumferential view of an embodiment of the coupling arrangement between the expansion cone segments and the split ring collar for use in the apparatus of Figs. 15 and 15a-15c.

5 Figs. 16 and 16a-16c are fragmentary cross-sectional illustrations of an embodiment of the placement of the apparatus of Figs. 15 and 15a-15j including an expandable tubular member within a borehole within a subterranean formation.

10 Figs. 17 and 17a-17c are fragmentary cross-sectional illustrations of an embodiment of the operation of the apparatus of Figs. 16 and 16a-16c during the radial expansion of the expandable tubular member within a borehole within a subterranean formation.

Fig. 18a is a cross sectional illustration of an embodiment of a segmented expansion cone assembly in an unexpanded position.

Fig. 18b is a fragmentary circumferential top illustration of the expansion cone and split ring collar of Fig. 18a.

15 Fig. 18c is a fragmentary cross-sectional illustration of the expansion cone support flange of the expansion cone assembly of Fig. 18a.

Fig. 18d is a cross-sectional illustration of the expansion cone support flange of Fig. 18c.

20 Fig. 19a is a cross sectional illustration of an embodiment of the segmented expansion cone assembly of Fig. 18a in an expanded position.

Fig. 19b is a fragmentary circumferential top view of the expansion cone of Fig. 19a.

Figs. 20a-20m are top circumferential views of various alternative embodiments of interlocking expansion cone segment geometries.

25 Detailed Description of the Illustrative Embodiments

Referring initially to Figs. 1 and 1a-1d, an embodiment of an apparatus and method for radially expanding a tubular member will now be described. As illustrated in Figs. 1 and 1a-1d, a wellbore 100 is positioned in a subterranean formation 105. In an exemplary embodiment, the wellbore 100 may include a pre-existing cased section 110. The wellbore 100 may be positioned in any orientation from vertical to horizontal.

30 In order to extend the wellbore 100 into the subterranean formation 105, a drill string is used in a well known manner to drill out material from the subterranean formation 105 to form a new wellbore section 115. In a preferred embodiment, the inside diameter of the new wellbore section 115 is greater than or equal to the inside diameter of the preexisting wellbore casing 110.

A tubular member 120 defining a passage 120a may then be positioned within the wellbore section 115 with the upper end 120b of the tubular member coupled to the wellbore casing 110 and the lower end 120c of the tubular member extending into the wellbore section. The tubular member 120 may be positioned within the wellbore section 115 and coupled to the wellbore casing 110 in a conventional manner. In a preferred embodiment, the tubular member 120 is positioned within the wellbore section 115 and coupled to the wellbore casing 110 using one or more of the methods and apparatus disclosed in one or more of the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent application serial no. 09/440,338, attorney docket no. 25791.9.02, filed on 11/15/1999, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, and (23) U.S.

provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001; and (24) U.S. provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, the disclosures of which are incorporated herein by reference.

5 As illustrated in Figs. 1 and 1a-1d, an apparatus 200 for radially expanding a tubular member may then be positioned in the new section 115 of the wellbore 100 within the tubular member 120. The apparatus 200 includes a tubular support member 205 defining an internal passage 205a that is coupled to an end of a tubular coupling 210 defining an internal passage 210a. The other end of the tubular coupling 210 is
10 coupled to an end of a tubular support member 215 defining an internal passage 215a that includes a first lug 215b, a radial passage 215c, a first flange 215d, a second flange 215e, a second lug 215f, and an expansion cone support body 215g. The other end of the tubular support member 215 is coupled to a tubular end stop 220 that defines a passage 220a.

15 As illustrated in Figs. 1e and 1f, the expansion cone support body 215g includes a first end 215ga, a tapered hexagonal portion 215gb that includes a plurality of T-shaped slots 215gba provided on each of the external faceted surfaces of the tapered hexagonal portion, and a second end 215gc. In an exemplary embodiment, the angle of attack of the tapered hexagonal portion ranges from about 35 to 50
20 degrees for reasons to be described.

As illustrated in Figs. 1, 1a-1d, 1g, 1h, and 1i, a plurality of expansion cone segments 225 are provided that include first ends 225a that include T-shaped retaining members 225aa and second ends 225b that include T-shaped retaining members 225ba that mate with and are received within corresponding T-shaped slots 215gba on
25 the tapered hexagonal portion 215gb of the expansion cone support body 215g, first external surfaces 225bb, second external surfaces 225bc, and third external surfaces 225bd. Thus, in an exemplary embodiment, a total of six expansion cone segments 225 are provided that are slidably coupled to corresponding sides of the tapered hexagonal portion 215gb of the expansion cone support body.

30 In an exemplary embodiment, the widths of the first external surfaces 225bb of the expansion cone segments 225 increase in the direction of the second external surfaces 225bc, the widths of the second external surfaces are substantially constant, and the widths of the third external surfaces 225bd decrease in the direction of the first ends 225a of the expansion cone segments for reasons to be described. In an
35 exemplary embodiment, the first external surfaces 225bb of the expansion cone segments 225 taper outwardly in the direction of the second external surfaces 225bc.

the second external surfaces taper upwardly in the direction of the third external surfaces 225bd, and the third external surfaces 225bd taper downwardly in the direction of the first ends 225a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the angle of attack of the taper of the first external surfaces 225bb of the expansion cone segments 225 are greater than the angle of attack of the taper of the second external surfaces 225bc. In an exemplary embodiment, the first and second external surfaces, 225bb and 225bc, of the expansion cone segments 225 are arcuate such that when the expansion cone segments 225 are displaced in the direction of the end stop 220, the first and second external surfaces of the expansion cone segments provide a substantially continuous outer circumferential surface for reasons to be described.

As illustrated in Fig. 1j, in an exemplary embodiment, the external surfaces, 225bb, 225bc, and 225bd, of the second ends 225b of the expansion cone segments 225 are adapted to mate with one another in order to interlock adjacent expansion cone segments.

As illustrated in Figs. 1, 1a-1d, and 1k, a split ring collar 230 that defines a passage 230a for receiving the tubular support member 215 is provided that includes a first end that includes plurality of T-shaped slots 230b for receiving and mating with corresponding T-shaped retaining members 225aa of the expansion cone segments 225 and a second end that includes an L-shaped retaining member 230c. In an exemplary embodiment, the split ring collar 230 is a conventional split ring collar commercially available from Halliburton Energy Services modified in accordance with the teachings of the present disclosure.

As illustrated in Figs. 1, 1a-1d, and 1m, a drag block assembly 235 that defines a passage 235a for receiving the tubular support member 215 is provided that includes a first end that includes an L-shaped slot 235b for receiving and mating with the L-shaped retaining member 230c of the split ring collar 230, one or more conventional drag block elements 235c, and a J-shaped slot 235d including a retaining slot 235da for receiving the second lug 215f of the tubular support member 215. In an exemplary embodiment, the longitudinal axis of the J-shaped slot 235d of the drag block assembly 235 is substantially parallel to the longitudinal axis of the tubular support member 215 for reasons to be described.

A first conventional packer cup assembly 240 that defines a passage 240a for receiving the tubular support member 215 includes a first end 240b that mates with the second flange 215e of the tubular support member, a conventional sealing cup 240c, and a second end 240d. A tubular member 245 that defines a passage 245a for

receiving the tubular support member 215 includes a first end 245b that mates with the second end 240c of the first packer cup assembly 240 and a second end 245c. A second conventional packer cup assembly 250 that defines a passage 250a for receiving the tubular support member 215 includes a first end 250b that mates with the second end 245c of the spacer 245, a conventional sealing cup 250c, and a second end 250d that mates with the first flange 215d of the tubular support member.

As illustrated in Figs. 1, 1a-1d, and 1l, a drag block assembly 255 that defines a passage 255a for receiving the tubular support member 215 is provided that includes a first end that includes sealing members, 255b and 255c, one or more conventional drag block elements 255d, and a J-shaped slot 255e including a retaining slot 255ea for receiving the first lug 215b of the tubular support member 215. In an exemplary embodiment, the longitudinal axis of the J-shaped slot 255e of the drag block assembly 255 is substantially parallel to the longitudinal axis of the tubular support member 215 for reasons to be described.

In an exemplary embodiment, during operation of the apparatus 200, as illustrated in Figs. 1 and 1a-1m, the apparatus may be positioned in the wellbore 115, within the tubular member 120, with the first and second lugs, 215b and 215f, respectively, positioned within the retaining slots, 255ea and 235da, respectively, of the J-slots, 255e and 235da, respectively, of the drag block assembly 255 and 235, respectively. In this manner, the drag block assembly 235 is maintained in a substantially stationary position relative to the tubular support member 215 thereby preventing the expansion cone segments 225 from being displaced downwardly in the longitudinal direction relative to the tubular support member 215 towards the end stop 220. Furthermore, in this manner, the drag block assembly 255 is also maintained in a substantially stationary position relative to the tubular support member 215 thereby preventing the drag block assembly from sealing off the radial passage 215c. In an exemplary embodiment, during the placement of the apparatus 200 within the wellbore 115 and the tubular member 120, the radial passage 215c permits fluidic materials outside of the tubular support member 215 to pass into the passage 215a thereby minimizing overpressure conditions within the annulus outside of the tubular support member.

In an exemplary embodiment, the apparatus 200 is positioned within the expandable tubular member 120 such that the expansion cone body 215g, the end stop 220, and the expansion cone segments 225 extend out of the expandable tubular member. In this manner, the expansion cone segments 225 may be driven up the tapered hexagonal portion 215ch of the expansion cone body 215g, thereby increasing

the outside diameters of the expansion cone segments, without impacting the expandable tubular member 120.

The tubular support member 215 may then be rotated relative to the drag block assemblies, 235 and 255, thereby displacing the lugs, 215f and 215b, with respect to the J-shaped slots, 235d and 255e, respectively. The tubular support member 215 may then be displaced upwardly relative to the drag block assemblies, 235 and 255, in the longitudinal direction thereby displacing the drag block assemblies downwardly relative to the tubular support member. During the longitudinal upward displacement of the tubular support member 215 relative to the drag block assemblies, 235 and 255, the drag block assemblies, 235 and 255, are maintained in a substantially stationary position with respect to the expandable tubular member 120 by the frictional forces exerted by the drag blocks, 235c and 255d, of the drag block assemblies on the expandable tubular member, and during the upward longitudinal displacement of the tubular support member 215 relative to the drag block assemblies, the lugs, 215f and 215b, are guided in a substantially longitudinal direction by the J-slots, 235d and 255e, respectively, of the drag block assemblies.

The downward longitudinal displacement of the drag block assembly 235 relative to the tubular support member 215 displaces the split ring collar 230 downwardly along with the expansion cone segments 225. As a result, the expansion cone segments 225 are driven up the tapered hexagonal portion 215gb of the expansion cone support body 215g until the end faces of the expansion cone segments impact the stop member 220. As a result, the outside diameter of the expansion cone segments 225 increases. In an exemplary embodiment, once the expansion cone segments 225 impact the stop member 220, the outer surfaces, 225bb and 225bc, of the expansion cone segments provide a substantially continuous outer surface in the circumferential direction having a diameter that is greater than the inside diameter of the expandable tubular member 120. The downward longitudinal displacement of the drag block assembly 255 relative to the tubular support member 215 seals off the radial passage 215c thereby preventing the pressurized fluidic material 275 from entering the annulus surrounding the tubular support member 215 through the radial passage.

In an exemplary embodiment, as illustrated in Figs. 2 and 2a-2f, the expandable tubular member 120 may then be radially expanded using the apparatus 200 by injecting a fluidic material 275 into the apparatus through the passages 205a, 210a, and 215a. The injection of the fluidic material 275 may pressurize the interior 120a of the expandable tubular member 120. In addition, because the packer cup assemblies, 240 and 250, seal off an annular region 120aa below the packer cup assemblies,

between the expandable tubular member 120 and the tubular support member 215, the injection of the fluidic material 275 may also pressurize the annular region.

The continued injection of the fluidic material 275 may then pressurize the interior 120a of the expandable tubular member 120 thereby plastically deforming and radially expanding the expandable tubular member off of the expansion cone segments 225. Because the outer surfaces, 225bb and 225bc, of the expansion cone segments 225 are tapered, the plastic deformation and radial expansion of the expandable tubular member 120 proximate the expansion cone segments is facilitated.

Furthermore, in an exemplary embodiment, the continued injection of the fluidic material 275 also pressurizes the annular region 120aa defined between the interior surface of the expandable tubular member 120 and the exterior surface of the tubular support member 215 that is bounded on the upper end by the packer cup assembly 240 and on the lower end by the expansion cone segments 225. Furthermore, in an exemplary embodiment, the pressurization of the annular region 120aa also radially expands the surrounding portion of the expandable tubular member 120. In this manner, the plastic deformation and radial expansion of the expandable tubular member 120 is enhanced. Furthermore, during operation of the apparatus 200, the packer cup assemblies 240 and 250 prevent the pressurized fluidic material 275 from passing above and beyond the packer cup assemblies and thereby define the length of the pressurized annular region 120aa. In an exemplary embodiment, the pressurization of the annular region 120aa decreases the operating pressures required for plastic deformation and radial expansion of the expandable tubular member 120 by as much as 50% and also reduces the angle of attack of the tapered external surfaces, 225bb and 225bc, of the expansion cone segments 225.

The radial expansion of the expandable tubular member 120 may then continue until the upper end 120b of the expandable tubular member is radially expanded and plastically deformed along with the overlapping portion of the wellbore casing 110. Because the expansion cone segments 225 may be adjustable positioned from an outside diameter less than the inside diameter of the expandable tubular member 120 to an outside diameter substantially equal to the inside diameter of the pre-existing casing 110, the resulting wellbore casing, including the casing 110 and the radially expanded tubular member 120, created by the operation of the apparatus 200 may have a single substantially constant inside diameter thereby providing a mono-diameter wellbore casing.

If the expansion cone segments 225 become lodged within the tubular member 120 during the radial expansion process, the tubular support member 215 may be

displaced downwardly in the longitudinal direction and then rotated relative to the drag block assemblies, 235 and 255, thereby positioning the lugs, 215b and 215f, within the retaining slots, 255ea and 235da, respectively, of the J-slots, 255e and 235d, respectively. As a result, the expansion cone segments 225 may be displaced down
5 the tapered hexagonal portion 215gb of the expansion cone support body 215g and away from the end stop 220 thereby decreasing the external diameter of the expansion cone segments. In this manner, the tubular support member 205, the tubular support member 210, the tubular support member 215, the end stop 220, the expansion cone segments 225, the split ring collar 230, the drag block assembly 235, the pack cup
10 assembly 240, the spacer 245, the packer cup assembly 250, and the drag block assembly 255 may then be removed from the tubular member 120.

During the radial expansion process, the expansion cone segments 225 may be raised out of the expanded portion of the tubular member 120 by applying an upward axial force to the tubular support member 215. In a preferred embodiment, during the
15 radial expansion process, the expansion cone segments 225 are raised at approximately the same rate as the tubular member 120 is expanded in order to keep the tubular member stationary relative to the new wellbore section 115. In an alternative preferred embodiment, the expansion cone segments 225 are maintained in a stationary position during the radial expansion process thereby allowing the tubular
20 member 120 to be radially expanded and plastically deformed off of the expansion cone segments 225 and into the new wellbore section 115 under the force of gravity and the operating pressure of the interior of the tubular member 120.

In a preferred embodiment, when the upper end portion of the expandable tubular member 120 and the lower portion of the wellbore casing 110 that overlap with
25 one another are plastically deformed and radially expanded by the expansion cone segments 225, the expansion cone segments 225 are displaced out of the wellbore 100 by both the operating pressure within the interior of the tubular member 120 and a upwardly directed axial force applied to the tubular support member 205.

In a preferred embodiment, the operating pressure and flow rate of the fluidic
30 material 275 is controllably ramped down when the expansion cone segments 225 reach the upper end portion of the expandable tubular member 120. In this manner, the sudden release of pressure caused by the complete radial expansion and plastic deformation of the expandable tubular member 120 off of the expansion cone segments 225 can be minimized. In a preferred embodiment, the operating pressure is
35 reduced in a substantially linear fashion from 100% to about 10% during the end of the

extrusion process beginning when the expansion cone segments 225 are within about 5 feet from completion of the extrusion process.

Alternatively, or in combination, the wall thickness of the upper end portion of the expandable tubular member 120 is tapered in order to gradually reduce the
5 required operating pressure for plastically deforming and radially expanding the upper end portion of the tubular member. In this manner, shock loading of the apparatus is at least reduced.

Alternatively, or in combination, a shock absorber is provided in the tubular support member 205 in order to absorb the shock caused by the sudden release of
10 pressure. The shock absorber may comprise, for example, any conventional commercially available shock absorber, bumper sub, or jars adapted for use in wellbore operations.

Alternatively, or in combination, an expansion cone catching structure is provided in the upper end portion of the expandable tubular member 120 in order to
15 catch or at least decelerate the expansion cone segments 225.

Alternatively, or in combination, during the radial expansion process, an upward axial force is applied to the tubular support member 215 sufficient to plastically deform and radially expand the tubular member 120 off of the external surfaces, 225bb and 225bc, of the expansion cone segments 225.

Alternatively, or in combination, in order to facilitate the pressurization of the interior 120a of the expandable tubular member by the injection of the fluidic materials 275, the region within the wellbore section 115 below the apparatus 200 may be
20 fluidically sealed off in a convention manner using, for example, a packer.

Once the radial expansion process is completed, the tubular support member 205, the tubular support member 210, the tubular support member 215, the end stop 220, the expansion cone segments 225, the split ring collar 230, the drag block assembly 235, the pack cup assembly 240, the spacer 245, the packer cup assembly 250, and the drag block assembly 255 are removed from the wellbore 100.
25

intermediate sizes. In this manner, the radial expansion and plastic deformation of the expandable tubular member 120 be provided in different operation stages, each having a different expansion diameter. Furthermore, if the expansion cone segments 225 become lodged within the expandable tubular member 120, then the position of the expansion cone segments may be adjusted to provide a smaller outside diameter and the radial expansion process may be continued by injecting the fluidic material 275 and/or applying an upward axial force to the tubular support member 215.

Referring to Figs. 3 and 3a-3j, an alternative embodiment of an apparatus 300 for forming a wellbore casing in a subterranean formation will now be described. The apparatus 300 includes a tubular support member 305 defining an internal passage 305a that is coupled to an end of a tubular coupling 310 defining an internal passage 310a. The other end of the tubular coupling 310 is coupled to an end of a tubular support member 315 defining an internal passage 315a that includes a first flange 315b having oppositely tapered end-walls, 315ba and 315bb, a second flange 315c, a radial passage 315d, a third flange 315e, a fourth flange 315f, a fifth flange 315g having oppositely tapered end-walls, 315ga and 315gb, a fifth flange 315h, and an expansion cone support body 315i. The other end of the tubular support member 315 is coupled to a tubular end stop 320 that defines a passage 320a.

As illustrated in Figs. 3d and 3e, the expansion cone support body 315i includes a first end 315ia, a tapered hexagonal portion 315ib that includes a plurality of T-shaped slots 315iba provided on each of the external faceted surfaces of the tapered hexagonal portion, and a second end 315ic. In an exemplary embodiment, the angle of attack of the tapered hexagonal portion 315ib ranges from about 35 to 50 degrees for reasons to be described.

and the widths of the third external surfaces 325bd decrease in the direction of the first ends 325a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the first external surfaces 325bb of the expansion cone segments 325 taper upwardly in the direction of the second external surfaces 325bc, the second external surfaces taper upwardly in the direction of the third external surfaces 325bd, and the third external surfaces 325bd taper downwardly in the direction of the first ends 325a of the expansion cone segments for reasons to be described. In an exemplary embodiment, the angle of attack of the taper of the first external surfaces 325bb of the expansion cone segments 325 are greater than the angle of attack of the taper of the second external surfaces 325bc. In an exemplary embodiment, the first and second external surfaces, 325bb and 325bc, of the expansion cone segments 325 are arcuate such that when the expansion cone segments 325 are displaced in the direction of the end stop 320, the first and second external surfaces of the expansion cone segments provide a substantially continuous outer circumferential surface for reasons to be described.

As illustrated in Fig. 3i, in an exemplary embodiment, the external surfaces, 325bb, 325bc, and 325bd, of the second ends 325b of the expansion cone segments 325 are adapted to mate with one another in order to interlock adjacent expansion cone segments.

A split ring collar 330 that defines a passage 330a for receiving the tubular support member 315 is provided that includes a first end that includes plurality of T-shaped slots 330b for receiving and mating with corresponding T-shaped retaining members 325aa of the expansion cone segments 325 and a second end that includes an L-shaped retaining member 330c. In an exemplary embodiment, the split ring collar 330 is a conventional split ring collar commercially available from Halliburton Energy Services modified in accordance with the teachings of

support member 315 is received within the opening 335ca of the tubular sleeve 335c that includes a recess 335fb for receiving the fifth flange 315h of the tubular support member 315 and the ring 335e, and a radial passage 335fc for receiving the pin 335d. Another end of the tubular coupling sleeve 335f includes a passage 335fd for receiving
 5 the tubular support member 315 and a slot 335fe for receiving the L-shaped retaining member 330c of the split ring collar 330. A ring 335g that defines a passage 335ga for receiving the tubular support member 315, a spring 335h, and a ring 335i that defines a passage 335ia for receiving the tubular support member 315 are also received within the recess 335fb. The ring 335g is positioned proximate one end of the recess 335fb,
 10 the ring 335i is positioned proximate the fifth flange 315h of the tubular support member 315 within the other end of the recess, and the spring 335h is positioned between the rings.

A first conventional packer cup assembly 340 that defines a passage 340a for receiving the tubular support member 315 includes a first end 340b that mates with the
 15 fourth flange 315f of the tubular support member, a conventional sealing cup 340c, and a second end 340d. A tubular spacer 345 that defines a passage 345a for receiving the tubular support member 315 includes a first end 345b that mates with the second end 340d of the first packer cup assembly 340 and a second end 345c. A second conventional packer cup assembly 350 that defines a passage 350a for receiving the
 20

315, a recess 355fe for receiving an end of the tubular sleeve 355c, and sealing members 355ff. A ring 355g that defines a passage 355ga for receiving the tubular support member 315 and a spring 355h are also received within the recess 355fb. An end of the ring 355g is positioned proximate the second flange 315c of the tubular support member 315 within an end of the recess 355fb and the other end of the ring is positioned an end of the spring 355h. The other end of the spring 355h is positioned proximate the other end of the recess 355fb.

In an exemplary embodiment, during operation of the apparatus 300, as illustrated in Figs. 3 and 3a-3j, the apparatus may be initially positioned in the wellbore 100, within the casing 110, with the collet assemblies 335 and 355 positioned in a neutral position in which the radial passage 315d of the tubular support member 315 is not covered by the tubular sleeve 355f and the expansion cone segments 325 are not driven up the tapered hexagonal portion 315ib of the expansion cone support body 315i of the tubular support member 315 into contact with the stop member 320. In this manner, fluidic materials within the interior 315a of the tubular support member 315 may pass through the radial passage 315d into the annulus between the apparatus 300 and the casing 110 thereby preventing over pressurization of the annulus. Furthermore

325 is maintained in a position that is less than the inside diameter of the tubular member 120 thereby permitting the apparatus 300 to be displaced within the tubular member. Furthermore, in this manner, an axial biasing force is applied to the tubular sleeve 355f thereby preventing the tubular sleeve from covering the radial passage 315d in the tubular support member 315. Thus, fluidic materials within the interior 315a of the tubular support member 315 may pass through the radial passage 315d into the annulus between the apparatus 300 and the tubular member 120 thereby preventing over pressurization of the annulus.

The apparatus 300 may then be at least partially positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120c of the tubular member 120. In an exemplary embodiment, that portion of the apparatus 300 that includes the stop member 320, the expansion cone segments 325, the split ring collar 330, the collet assembly 335, the packer cup assembly 340, the spacer 345, the packer cup assembly 350, and the collet assembly 355 is then positioned in the open hole section 115a of the wellbore section 115, beyond the lower end 120 of the tubular member for reasons to be described. Because the collets, 335b and 355b, are resilient, once the apparatus 300 has been positioned in the open hole section 115a of the wellbore

the apparatus 300 to be used to radially expand and plastically deform the tubular member, and fluidic materials within the interior 315a of the tubular support member 315 may no longer pass through the radial passage 315d into the annulus between the apparatus 300 and the tubular member thereby permitting the interior of the apparatus
 5 to be pressurized.

The apparatus 300 may then be operated to radially expand and plastically deform the tubular member 120 by applying an upward axial force to the tubular support member 315 and/or by injecting a pressurized fluidic material into the tubular support member.

10 In particular, as illustrated in Figs. 5 and 5a

for plastic deformation and radial expansion of the expandable tubular member 120 by as much as 50% and also reduces the angle of attack of the tapered external surfaces, 325bb and 325bc, of the expansion cone segments 325.

The radial expansion of the expandable tubular member 120 may then continue
 5 until the upper end 120b of the expandable tubular member is radially expanded and plastically deformed along with the overlapping portion of the wellbore casing 110. Because the expansion cone segments 325 may be adjustable positioned from an outside diameter less than the inside diameter of the expandable tubular member 120 to an outside diameter substantially equal to the inside diameter of the pre-existing

required operating pressure for plastically deforming and radially expanding the upper end portion of the tubular member. In this manner, shock loading of the apparatus is at least reduced.

Alternatively, or in combination, a shock absorber is provided in the tubular support member 305 in order to absorb the shock caused by the sudden release of pressure. The shock absorber may comprise, for example, any conventional commercially available shock absorber, bumper sub, or jars adapted for use in wellbore operations.

Alternatively, or in combination, an expansion cone catching structure is provided in the upper end portion of the expand

shaped slots 415jba provided on each of the external faceted surfaces of the tapered hexagonal portion, and a second end 415jc. In an exemplary embodiment, the angle of attack of the tapered hexagonal portion 415jb ranges from about 35 to 50 degrees for reasons to be described.

A split ring collar 430 that defines a passage 430a for receiving the tubular support member 415 is provided that includes a first end that includes plurality of T-shaped slots 430b for receiving and mating with corresponding T-shaped retaining members 425aa of the expansion cone segments 425 and a second end that includes an L-shaped retaining member 430c. In an exemplary embodiment, the split ring collar 430 is a conventional split ring collar commercially available from Halliburton Energy Services modified in

resilient dog 455b. A second end of the tubular sleeve 455a includes a recess 455ac and is coupled to an end of a load transfer pin 455c. The opposite end of the load transfer pin 455c is coupled to a retaining ring 455d that defines a passage 455da for receiving the tubular support member 415. A tubular sleeve 455e is received within the
 5 recess 455ac of the

sleeve 435a that prevents the expansion cone segments 425 from being displaced toward the end stop 420. As a result of the backward axial displacement of the resilient dog 455b, the tubular sleeve 455a, the pin 455c, the retaining ring 455d, and the ring 455g of the dog assembly 455 are driven backward thereby compressing the spring 455f and applying an

coupling the radial passages 415c and 415d. As a result fluidic materials within the tubular support member 415 may not pass into the annulus between the tubular support member and the tubular member 120.

As a result of the forward axial displacement of the resilient dog 435e, the
 5 outside diameter of

120. In this manner, the plastic deformation and radial expansion of the expandable tubular member 120 is enhanced. Furthermore, during operation of the apparatus 300, the packer cup assemblies 440 and

segments 425 can be minimized. In a preferred embodiment, the operating pressure is reduced in a substantially linear fashion from 100% to about 10% during the end of the extrusion process beginning when the expansion cone segments 425 are within

outwardly from the tubular body in the radial direction that each include identical bases 505cba and extensions 505cbb. The support members 505cb

510ba. In an exemplary embodiment, the outer conical surfaces 510baa of the expansion cone segments 510ba in the expanded position of the assembly 500 provide

retaining member 615c. A tubular sleeve 620 is provided that defines a passage 620

includes a tubular support member 705 that

